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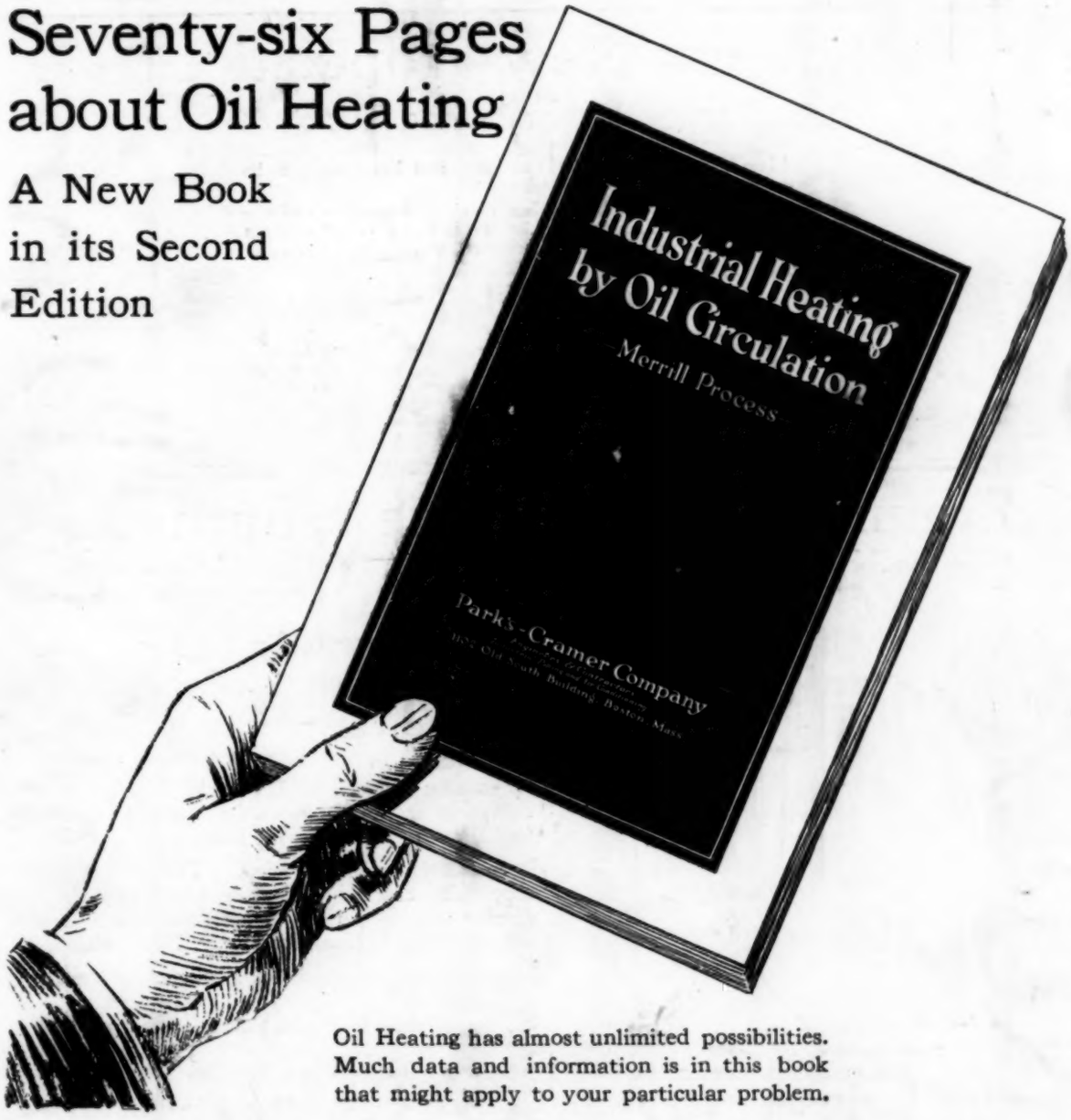

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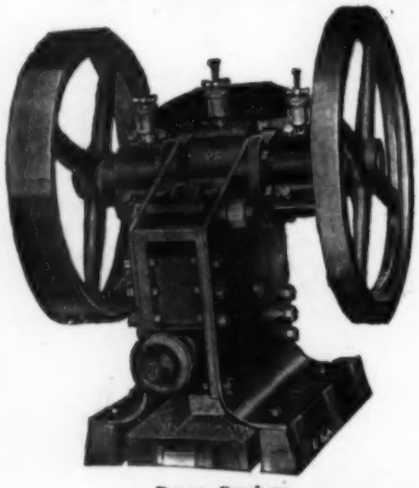

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CHEMICAL & METALLURGICAL ENGINEERING

A consolidation of
ELECTROCHEMICAL & METALLURGICAL INDUSTRY *and* IRON & STEEL MAGAZINE
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Volume 26 — New York, March 1, 1922 — Number 9

Patent Legislation Will Benefit Industry

INDUSTRY will receive many direct benefits as a result of the passing and signing of the bill to relieve conditions in the Patent Office. As soon as the necessary appropriations can be made it will be possible to increase the force by 10 per cent and salaries by 45 per cent. As much as $450,000 per annum will be added to the payroll. These figures are not mentioned in a spirit of elation, because Congress has long been niggardly with the Patent Office and has neglected a self-supporting institution to the detriment of the country's business. The new salaries authorized are still inadequate, but they will afford sufficient relief to prevent a complete disintegration of the Patent Office staff.

When the full force of the new bill is in effect it will be possible to get prompter action on applications for patents. And with promptness will come a higher degree of efficiency that should reduce the amount of litigation that arises from hurried consideration of patent claims. Inventors will not be discouraged by interminable delay that has characterized Patent Office procedure for the past few years. This was coming to be a very serious matter, even threatening the acknowledged supremacy of the United States in stimulating the inventive genius of its people.

An important feature of the bill is an amendment enabling a patentee to recover cash damages for infringement of his patent. Hitherto it has been exceedingly difficult to obtain such damages, but the present bill provides for a means of accounting that simplifies matters and makes reasonable compensation a certainty.

All in all we may feel encouraged over the consummation of this legislation, but we should be constantly on guard to see that the Patent Office does not again fall into such dire straits.

Mr. Ford As a Catalyst

IT WOULD BE ironical if the sequence of events in the final disposition of Muscle Shoals should prove that HENRY FORD and his offer for the power and nitrate plants served merely to stimulate others to bring more acceptable proposals before the government. Such is likely to be the case, however, if we may judge from the terms on which the Alabama Power Co. has already proposed to buy the power plants and complete the Wilson dam under the federal water-power act.

We hold no brief for the Alabama Power Co. or for any other individual or corporation that may bid on these government properties, but it is gratifying to see in the power company's proposal a vindication of our contention that Muscle Shoals should be looked upon as two separate and unrelated projects, one a water-power development and the other a chemical-manufacturing plant. The power company in its bid proposes to complete the Wilson dam and hydro-electric power plants at its own expense and offers a fixed quantity of power per annum for government use. No reference is made to the nitrate plants. They would still be left at the disposal of the government either to be kept in standby condition for the Ordnance Department of the Army or sold to some private concern. In other words, the offer of the Alabama Power Co. is more attractive than that of Mr. FORD.

We may contrast the two in their vital points: Mr. FORD would have the government finance the completion of the power project; the Alabama Power Co. will finance its own operations. Mr. FORD asks a 100-year lease, with further prior rights on power at the end of that period; the power company asks only a 50-year lease, with provision for recapture of the project by the government at the end of that period. Mr. FORD offers $5,000,000 for the nitrate plants, the Gorgas-Warrior steam plant, the lime quarry and other accessories; the power company will pay an equal amount for the same accessories omitting the nitrate plants. In addition the power company offers to furnish free to the government, or to anyone it may designate, 100,000 hp. as required for the production of fertilizers and munitions of war and for research in connection therewith. In our judgment the contrast is sufficiently impressive to warrant the belief that the Ford offer will not be acceptable to the government.

A Final Word On the Bonus

IT HAD NOT been our intention to comment again on the soldier bonus, but letters from subscribers, published elsewhere in this issue, led us to give final consideration to the subject. It is evident now that Congress gave quite as much heed to the wave of opposition as it did originally to the supposed demand for the bonus, and the prospect of legislation is very remote. That the country will have none of it is apparent even to those who are not accustomed to keeping their political ears to the ground. In Congress, what was first supposed might prove a strong political weapon has assumed the properties of a boomerang.

Those who disagreed with our stand on this question have not refuted our principal argument, which is that legislation for a cash bonus will be an economic blunder. It is beside the point to refer to the action of individual states that have already passed bonus legislation. There are others that have not and will not. Doubtless those that have will wish they had not if a federal tax is now laid to pay a national bonus. Some of our critics cite the compensation that was paid to those who lost on war contracts and to others who were financially disabled by the war, and argue that the ex-service

man should be similarly compensated for loss of money and position. It would not be difficult to cite many instances of civilians to whom the war brought financial loss and for whom there is no hope of compensation. War brings its fortunes and misfortunes that cannot possibly be equalized or balanced. The country is sympathetic with the disabled soldier and feels that everything should be done to relieve his sufferings and rehabilitate him, but it is not moved by the same sort of sentiment for the able-bodied survivor.

Nor do we share the assurance of our correspondent who asserts that "business was not in the trenches." We can imagine some business men waxing eloquent in response to that challenge! But granting that business wasn't in the trenches during the war, it is today knee deep in the mire of economic readjustment that will only be made deeper and stickier by a bonus award.

If the general idea of a bonus of $500 or $600 were acceptable, we still think that the proposed method of distribution would be inefficient. As the plan now stands, it is about as fine a scheme as can be devised for dissipating hundreds of millions of dollars by paying it out in such small doles and at such intervals that the most of it will be squandered.

Three of our critics raise a point which, while it has no bearing on the bonus, ought not to pass without comment. They question the independence of thought and action on the part of members of our editorial staff. The only reply that need be made is that the editor is not subservient to higher authority in determining the policy of CHEM. & MET., nor are members of the staff under the slightest coercion to agree with the editor's views. If, as in the present instance, the entire staff is in accord, its members have sacrificed none of their independence, nor have they bowed submissively to a tyrannical authority. Editorial independence is one of the first requisites of a virile magazine.

Royal Houses In Chemistry

IT CERTAINLY is a pleasure to see the young fellows coming along. Somebody with great imagination "binds time" in science by adding his contributions to the records of human progress and then passes them on for future generations. The subjects endure, but the names change. Occasionally, however, there is a strain among families of men in which the gift for research perseveres and when we see it manifest itself in successive generations, it gives us an agreeable thrill.

Research seldom provides riches or palaces or even the appearance of luxury or ease. The truly great look like other men, and with a few curious exceptions they are modest and kindly and generous; inspired, as are all good men, with a sense of their obligations to contribute as much as they can. Despite the apparent democracy, however, they are aristocrats of the first rank, and their spiritual abode is in the temple of fame.

There is, for instance, ARRHENIUS—SVANTE ARRHENIUS. He has already done a giant's work. His fame is secure. And we wish him many years of continued research and the abundant joys of discovery. The name itself has a classic tang, and it does not surprise the student when he finds electrolytic dissociation and even a happy suggestion on the origin of life on earth coupled with it. It looms above the boundaries of nations. He is ARRHENIUS the First!

We call him the First, because there appears above the horizon of the great domain of Science a second of the line, OLOF ARRHENIUS, the son of SVANTE, and OLOF has lately been at work with THEODORE W. RICHARDS in the Wolcott Gibbs Memorial Laboratory at Cambridge. He presents a very acceptable contribution in the January number of the *Journal of the American Chemical Society* on "Quantitative Analysis by Centrifuge." The method has been used for special purposes and now he makes it more general for the rapid determination of calcium, magnesium and phosphoric, sulphuric and nitric acids.

> The precipitate obtained in the usual way is shaken with the mother solution and then transferred to tubes 2.5 cm. in diameter at the top, and provided with a steep funnel below leading to a capillary tube about 4 cm. long (and for compact precipitates only 1 mm. in bore). The precipitate is allowed to settle in the capillary stem. Many of these tubes are then centrifuged together, until the precipitate in each has attained a constant height, which is usually the case in less than half an hour. This column is read with a mirror scale to avoid parallax in reading. These columns are reduced to a weight standard by comparison with a precipitate similarly obtained from a known weight of the substance similarly treated.

Only a modest contribution, to be sure, and there have been others before it, but this one is potent for the convenience of chemists. It is likely to find its way into many laboratories, and to stay there. We can imagine, 'way off in the next century, some chemist coming home from his laboratory earlier than usual, and a greeting awaiting him the more ardent and agreeable because he came before he was expected. "Who helped you through with your work so soon?" is a question that may be put. And an answer that may be given is "ARRHENIUS the Second!"

Import and Export Of Nitrogen

CROSS-HAULING of commodities to satisfy unnecessary and unwarranted individual preference is a demonstrated economic waste. A similar economic extravagance occurs in simultaneous import and export of equivalent material. It is, therefore, of importance to the nitrogen-producing and the nitrogen-using industries of America to determine whether there is not now going on some such international movement of ammonia and nitrate compounds.

During 1921 there was imported into the United States approximately 370,000 tons of Chilean nitrate, valued at $18,000,000. During the same year about 103,000 tons of ammonium sulphate, valued at $6,100,000, was exported. These two items represent the major transactions in international movement of inorganic nitrogen compounds in which the United States is interested. In the imported nitrate there was about 55,000 tons of nitrogen. In the exported sulphate there was about 20,000 tons of nitrogen. In other words, about 36 per cent of the nitrogen that is imported is represented by equivalent exports of nitrogen in other forms.

There is no doubt that not all of the nitrate can be replaced by ammonium sulphate, for there is a real function to be served in fertilizers as elsewhere by the nitrate nitrogen which is not so well served by ammonia nitrogen. Nevertheless it is time to take account of stock and determine whether we are, to the maximum practical extent, using ammonia nitrogen for the replacement of nitrate nitrogen. If we are not, then it would be better to use some of this domestic production of ammonium sulphate and import somewhat less of Chilean nitrate for this purpose.

The Inevitable Economic Reaction

THOSE who have studied internal conditions in Germany have for some time prophesied that it would be wholly impossible to continue there much longer upon the system of subsidizing labor and industry by government budgets. Apparently the reaction from that false economic system is coming now. In any event, certain evidence which is accumulating tends to show that a new basis of industrial relation with Germany will develop within the next few weeks, or at the longest within the next few months.

Industrial costs depend largely upon the cost to the manufacturer of money, men and material. Definite information from German sources indicates that forced loans to the government are tending radically to reduce existing reserves and to enhance money costs to industry. Freight rates advanced about 33 per cent on Feb. 1, and the tax upon coal was increased to 40 per cent at the same date, so it is reported. The wage index of the *Frankfurter-Zeitung* shows increase from July, 1921, to January, 1922, of surprising percentages for labor in various industries. Some of those which are quoted from that source are: Chemical industries, 46 per cent increase; metallurgical industry, 78; shoe and leather industry, 50; woodworking, 60; building, 85; foodstuffs industry, 67.

The internal purchasing power of the mark is quoted as having decreased from 5.35 in January, 1920, to 1.76 in October, 1921. The "all-commodity" index of wholesale prices in German marks stood at 3,814 on Feb. 5, 1922, as compared with 3,467 in the preceding month, 3,233 in December, 1921, 1,484 a year ago and 100 in the middle of 1914. This decrease in purchasing power of the mark for domestic transactions is quite believable when one learns of the decree that was to take effect Feb. 16, that bread should cost 75 per cent more after that date than before it. It is not surprising, in view of these facts and the multitude of others like them, that the wage problems of German industries are by no means easily solved.

Germany tried a system in industry quite as fallacious in its economic groundwork as the Soviet economics of Russia. It was reasoned that by large units of industry such efficiency could be gained that the government might properly subsidize the formation of such industry and might by indirection keep the nominal wage and the market price of commodities below the level which normal influences of trade would have caused them to reach. It has been amply demonstrated, however, that the government cannot thus long subsidize business. The budget of the government by any such system becomes so badly unbalanced as soon to be unstable; and with the removal of the subsidy the readjustment which follows is likely to be much more disastrous than the normal and gradual adjustment that results in consequence of unrestricted movement of wage and price levels.

American industry, which must inevitably in many lines compete with German production, can find some measure of comfort in these tendencies. But it is too much to hope that these economic laws will altogether do away with the difference in costs in Germany and in this country. To assume such a result as that is to assume that the German nation is capable of providing for itself as high a standard of living for its working classes as American conditions have provided for the American wage earner.

Quantitative Economics And Invention

ONE of the slogans during the war was: "Produce more, consume less." That was quantitative economics. Our production and consumption had been approximately equal, but to find the things necessary for prosecuting war it was necessary that total production be increased and consumption, apart from the prosecution of war, be decreased. This relatively new science of quantitative economics promises to be interesting, which the old science of political economy was not. It is a science made possible by the fact that we now have much statistical matter measuring the industrial activity of the country, when in the old days we did not have such information.

One of the applications of quantitative economics is to determine whether we can do things we are trying to do or hope to do. There is the application to this question of the "living standard" which the labor leaders have been insisting on. In this department of CHEMICAL & METALLURGICAL ENGINEERING of Dec. 14, 1921, reference was made to the very interesting findings of the National Bureau of Economic Research, showing the national income for a period of years, expressed in dollars, converted into income per capita and adjusted to the 1913 dollar, whereby the income was expressed in its commodity purchasing power. This showed that on an average the individual income would purchase but little more than before the war, hence a raising of the "living standard" of any large number of people was impossible.

Another application of quantitative economics is to the growth of individual industries. Many industries have grown in the past half century at remarkably great rates, showing practically a geometrical ratio of progression. For instance, for a long time the production of pig iron substantially doubled every 10 years, while the freight ton-mileage of the railroads doubled every 12 years. For a time the production of coal increased at a more rapid rate still. The production and use of passenger automobiles, pleasure vehicles, increased very rapidly for a time. Men interested particularly in any one industry wish to see it grow and continue to grow, but quantitative economics informs us that everything cannot grow rapidly unless there are new developments to make it possible. Men cannot be taken from iron ore mines to operate railroad trains, and from railroad trains to make automobiles and from automobile factories to dig coal.

Quantitative economics shows that as a nation we cannot take out more than we put in, yet that is what we want to do. The only way out is to produce more per capita, and that means inventions. Since 1913 inventions along this line have been much less important than formerly.

We are looking forward to a great improvement in industrial conditions in the next few years, but we cannot compass that simply by doubling up on everything. Undoubtedly a great many men could be found whose idea is that the industry in which they are particularly interested should, as a new normal, operate at one-half greater pace than in 1913. Obviously that cannot be done without improvements, without a corresponding increase in efficiency. We cannot have 50 per cent more men engaged in mining coal, consuming coal, moving freight, producing iron, consuming iron, and so on all along the line. The individual workers must produce more, then they can consume more.

Readers' Views and Comments

On the Heat-Treatment of Aluminum Bronze

To the Editor of Chemical & Metallurgical Engineering

SIR:—A. A. Blue's paper "On the Heat-Treatment of Aluminum Bronze" in your issue of Dec. 7, 1921, gives a good introduction to the subject. Unfortunately, he ceased his own efforts to heat-treat and test these interesting alloys before be succeeded in obtaining satisfactory results. As he admits that the results given in Table IV were obtained by an inferior method of testing and in part on unsound bars, it would seem that the paper would have been of more value and less misleading had this table been omitted. However, it has some value in pointing out the reason for the author's astonishing conclusion that "heat-treatment produces little or no effect on yield point," for when a bar of this alloy containing 10.39 per cent aluminum is quenched in water from 1,780 deg. F., and then gives 9 per cent elongation in a tensile test, it is positive proof that the heating or quenching operation was improperly performed. A proper quenching of this material would lower the elongation to not over 2 per cent at the maximum, and if not properly quenched, the yield point cannot be expected to be raised either in the quenched or in the quenched-and-tempered bars.

The present writer had been all through this stage of the game with aluminum bronze before he finally learned the various causes of poor results and how to avoid them. It is a simple matter to do some hasty work on almost any material, getting poor results, and then to write a paper about them condemning the material.

It is entirely possible to obtain strengths of 100,000 lb. per sq.in. even with cast aluminum bronze of proper composition, properly treated, in spite of Mr. Blue's failure to reach this figure. The writer has obtained this result, not merely from one test, but from an average of several tests of different heats. All conditions must be right, of course, to reach this figure in a casting, or some little defect will creep in somewhere and lower the result, but with forged material it should be a simpler proposition. It is also possible to double the yield point and proportional limit of 10 per cent aluminum bronze by proper heat-treatment, as the writer knows from personal experience with numerous tests over a period of years, some of the tests having been checked and corroborated by the Bureau of Standards. Such treatment results in elongations between 8 and 15 per cent and also gives a decided increase in tensile strength.

The conclusion that aluminum bronze is difficult to handle in the foundry is entirely correct, though the bearing of the paper on this point is hard to find. Still there are foundries where this alloy can be produced consistently.

One other point is open to criticism in this paper, and that is the author's indefinite use of the term "annealing," which he confuses with tempering or drawing after quenching. The structures shown by Figs. 12, 13 and 14, for instance, are evidently of quenched and tempered alloys, and could scarcely be the result of simple annealing, as might be understood from the title. There is, moreover, no mention in the paper of the important fact that simple annealing of this cast alloy, unquenched, increases its hardness slightly and spoils its tensile properties, decreasing both strength and ductility.

GEORGE F. COMSTOCK,
Niagara Falls, N. Y. Metallurgical Engineer.

To the Editor of Chemical & Metallurgical Engineering

SIR:—In the article written by A. A. Blue, "On Heat-Treatment of Aluminum Bronze," and published in your issue of Dec. 7, 1921, there are a few points and conclusions with which no one who knows aluminum bronze can agree.

The writer agrees with Mr. Blue's conclusion 2, that heat-treatment produces marked and consistent changes in Brinell and scleroscope hardness, but conclusion 3 is the opposite of what my experience and that of others show.

In Table II Mr. Blue tabulates hardness tests after various heat-treatments which are not readily comparable on account of variation in composition. Variation of 0.5 per cent Al is not tolerable in this region of Al-Cu alloys for comparative tests.

Table IV of his article gives puzzling results of physical tests after various heat-treatments. Most if not all of the figures in this table do not check with those obtained by other investigators—for instance, with results of H. C. H. Carpenter and C. A. Edwards. They are not consistent—e.g., test 158 gives tensile strength 61,000, yield point 19,000 and elongation 20.5 per cent for material as cast, and for the same material after quenching, test 161 reports tensile strength 69,500, yield point 20,000 and elongation 3 per cent.

Another anomaly can be seen on page 1048, where Mr. Blue gives the following properties for a bar quenched from 1,700 deg. F., drawn at 1,000 deg. F. and cooled in lime: Tensile strength 79,480 to 81,495, yield point 20,000 to 32,500 and elongation 20 to 22.5 per cent. From numerous tests I have found it impossible to obtain 20 per cent elongation by drawing aluminum bronze of this composition at this low temperature; 2 to 5 per cent is all that can be expected and the yield point would be correspondingly higher, 50,000 to 60,000 lb. per sq.in.

The theory of heat-treatment of aluminum bronze is simply this: By heating to proper temperature all of the alpha phase is absorbed; by quenching, this condition is retained, resulting in high tensile strength, yield point and hardness, and low elongation. By drawing at proper temperature above the transformation point, a desired amount of alpha phase is restored, resulting in an alloy of lower tensile strength, yield point and hardness than the quenched alloy, but higher in elongation. The higher the drawing temperature the lower the tensile strength, yield point and hardness, and the higher the elongation. The proper temperature for quenching is evident even from Mr. Blue's photomicrographs, Figs. 15 to 20. The proper temperature for drawing must be always above the transformation point, and the temperature of 1,000 deg. F. used by Mr. Blue cannot result in restoring any alpha phase and increasing the ductility; on the contrary, it may cause decomposition of beta phase into eutectoid, resulting in a still harder alloy. This increase in brittleness and hardness at low draws was noticed

by Mr. Blue is his impact, compression and hardness tests. Therefore, obtaining 20 per cent elongation after quenching from 1,700 deg. F. and cooling slowly from 1,000 deg. F., is an anomaly which alone would tell the investigator not to be satisfied with his tests.

In our experience there has been no exception to the fact that sound aluminum bronze of 90:10, or 89:10:1 (Fe) responds to the proper heat-treatment, and our representative figures for aluminum bronze as cast, and after heat-treatment, are as follows:

	Tensile Strength	Yield Point	Elongation	Brinell
As cast	65,000 to 70,000	25,000 to 30,000	20 to 25	90 to 100
Quenched	85,000 to 95,000	60,000 to 70,000	1 to 2	220 to 240
Quenched and drawn	80,000 to 93,000	50,000 to 60,000	4 to 10	187 to 200

From these figures it is evident that the heat-treatment does produce a considerable change in tensile strength and yield point, as well as in hardness and elongation. It is also evident that Brinell hardness and tensile strength correlate, which is not in accordance with Mr. Blue's findings. In our practice of heat-treatment of castings we use Brinell test for checking the heat-treatment and for judging the tensile strength and elongation of the material after heat-treatment. This practice, of course, was preceded by exhaustive tests proving that Brinell hardness and the other physical properties correlate sufficiently. Here it may be mentioned also that the results obtained on aluminum bronze test-bars cast to shape (1 in. diameter), and test-bars cut out of a casting, give approximately the same result—unlike other bronzes.

Mr. Blue's forging experiments are also insufficient and the forging is followed by erroneous method of heat-treatment. But even those, as well as our own experiments, indicate that by forging it is possible to combine a high tensile strength with high elongation. Mr. Blue states, "The results show some improvement in tensile properties, but an increase in brittleness in the heat-treated specimens." But this increase in brittleness is due not to forging, but to the faulty heat-treatment—viz., drawing at 1,000 deg. F. and cooling in lime. This treatment will result in brittle metal independent from previous treatment, and this Mr. Blue could have seen from the equilibrium diagram which he included in his paper.

BRUNO WOYSKI,
Chief Metallurgist.
Lumen Bearing Co.,
Buffalo, N. Y.

To the Editor of Chemical & Metallurgical Engineering

SIR:—In reply to criticisms by Messrs. Comstock and Woyski, I would say in the first place, the material used in the majority of the tests recited in this paper, including all of the tensile, impact and compression tests, was purchased from the Lumen Bearing Co. and a number of actual castings which were tested and failed in practical tests were treated by the Lumen Bearing Co. and another lot by Mr. Comstock personally. These castings behaved in the same manner as those treated in our furnaces and failed at the same loads. In order to indicate that these tests were not unreasonable, another type of bronze was later obtained which has stood up satisfactorily under the same tests.

Concerning the criticisms of testing methods, it may be mentioned that all of the tensile, impact and compression tests were carried out in the laboratory of the Carnegie Institute of Technology, under the personal supervision of Prof. F. M. McCollough, the head of the department, which leaves no doubt as to the fact that the figures reported represent the properties of the material tested.

It was the purpose of the paper in question, as pointed out in the first paragraph, to be of value to those interested "in what results they may expect to obtain from it under actual conditions of its everyday practical manufacture and treatment." Without, therefore, going into a detailed discussion of metallurgical considerations involved, the following should be mentioned:

In the last paragraph of Mr. Comstock's letter, unwarranted liberty has been taken with the original paper as regards Figs. 12, 13 and 14. The structures shown in these photographs were obtained, as noted in the caption attached, by "annealing," and not by "tempering or drawing after quenching," as Mr. Comstock supposes. The samples were heated to the temperatures indicated, and permitted to cool as noted, no quenching whatever being involved. Included in the same paragraph, Mr. Comstock states that no mention has been made of "the important fact that simple annealing of this cast alloy, unquenched, increases its hardness slightly and spoils its tensile properties." As a matter of fact, Figs. 22 and 23 show that simple annealing *decreased* the hardness, both Brinell and scleroscope, which was brought out in the text on page 1045, last paragraph.

Referring to Mr. Woyski's communication, the chief point of this criticism hinges upon the heat-treatments given, especially exception being taken to the use of a drawing temperature of 1,000 deg. F. We understood that a number of the castings treated by Mr. Comstock to make them suitable for our purposes were drawn back to this same temperature—i.e., 1,000 deg. F. Our understanding is that this also applies to similar castings treated and furnished by Mr. Woyski's company.

In conclusion, the matter is, of course, simply the old one of buyer and seller. We are interested not in what *may possibly* be done with aluminum bronze, but in what *can always* be done with it day after day, so that we may rely upon it in insuring our own customers in using our product. It failed to meet these requirements, first, when tried out in actual service tests; second, in the tests described in the paper in question, and, third, after the personal efforts of other metallurgists to make it do so. In view of the large amount of money and time expended in these tests, covering nearly a year's time, the results were distinctly disappointing. Therefore we were forced to the conclusion, as mentioned, that a number of the published figures concerning this material were unreliable as an indication of what it would do in a practical way. We know of no reason for changing this conclusion. Aluminum bronze has many novel features, and is an interesting material in the laboratory, which has, no doubt, led its enthusiastic adherents to make claims for it which actual practice will hardly justify. On the other hand, it possesses many features of technical importance, prominent among which should be mentioned its excellent bearing qualities. In fact, we use it regularly in a number of parts where only moderate stresses are involved, with complete satisfaction. However, for heavy duty work, as mentioned above, we have found another bronze to be more satisfactory and to be in better accord with the figures claimed for it, the following being an example: Tensile strength, 101,990 lb.; yield point, 62,250 lb.; 14.5 per cent elongation; 17.4 per cent contraction.

A. A. BLUE.
The Duff Manufacturing Co.,
Pittsburgh, Pa.

The Soldier Bonus

To the Editor of Chemical & Metallurgical Engineering

SIR:—Just a word about the soldier bonus to describe how the situation strikes one of that great mass of ex-soldiers who have so far said nothing but have quietly watched the agitation for and against.

Visualize the following, if you can:

The fair daughter of a corpulent, well-dressed individual, radiating prosperity, has just been rescued from a watery grave by the noble efforts of one of the corpulent gentleman's workmen at the risk of his life. The corpulent individual is moved to tears, and is loud in his praise of the hero. But wait! The corpulent gentleman, having given profuse thanks, now attempts to depart. The hero, however, demands a reward. The face of the corpulent individual changes immediately. No, he is too poor; it would ruin him; must he not buy his daughter more clothes for the ones that are spoiled?

Picture now the corpulent individual hounded by the hero for his gratuity. Is it not laughable, ridiculous, even painful to consider? Both have lost the last shred of the spectators' respect. From the sublime to the ridiculous!

It is difficult to conceive of anyone consoling either of these figures. However, of the two I must admit that my sympathies are decidedly with the unsatisfied hero.

To begin with, it was certainly bad taste for the "hero" to demand a reward, but was it not worse taste, on the business man's part, not to offer one?

The whole situation is disgusting in the extreme in that it has not only to a large extent debased the gratitude due ex-soldiers, but has shown American business in the light that European nations have viewed it for years, but to which true Americans have long tried to blind themselves.

Down with honor! Up with the DOLLAR $!

N. F. WILSON, JR.

Philadelphia, Pa.

SAYS BUSINESS WAS NOT IN THE TRENCHES

To the Editor of Chemical & Metallurgical Engineering

SIR:—The reason our government is not more representative is because most of us are not interested enough to take the trouble to raise our voices in defense of legislation we favor or to protest when we are not in favor.

To be sure, business does not want the soldier bonus, but business was not in the trenches or the camps. I was not sent overseas and therefore do not feel entitled to the bonus. No sum of money would be enough to be considered "in full for services rendered." The men who helped build Hog Island were not paid the same wages as the men who "fought their way through the Argonne."

It is not for the members of the American Legion as such to make suggestions to solve this problem, for the country did not ask the soldiers how to carry on the war; it asked them only to fight. RICHARD RIMBACH.

Butler, Pa.

SAY EX-SERVICE MAN ASKS ONLY JUSTICE

To the Editor of Chemical & Metallurgical Engineering

SIR:—As readers of your magazine, we wish to take exception to certain statements made with reference to the soldier bonus. We do not believe that we are in the minority in supporting this measure, as public sentiment, wherever taken, has proved that the compensation of ex-service men is very popular. Ohio recently approved a state bonus by a 3½ to 1 vote. Several of the chambers of commerce, notably the Cleveland Chamber of Commerce, have approved the measure.

Speaking as one "having experience, if not authority," you mention that five members of your staff are opposed to the bonus. After your first editorial, it is doubtful if they would come out openly in favor of the measure and still hope to retain their positions.

The principal argument, and one which we have not seen satisfactorily answered, is that compensation was paid to those who lost on war contracts, to the railroads and to civilian employees of the government. The ex-service man, who lost not only money but also the advancement which came to those who remained in civil life, asks only for justice. JAMES C. WEBSTER,
V. M. BURROWS,
EDMUND WENDEL.

Cleveland, Ohio.

Colloidal State in Metals and Alloys

To the Editor of Chemical & Metallurgical Engineering

SIR:—I have read with much interest Mr. Alexander's contribution and should like to congratulate you upon the very interesting manner in which he is dealing with this subject. The matter is one of great industrial importance and while being much interested in the colloidal aspect which the author introduces, I suggest that, as regards the experimental evidence which he considers, he should be more precise, when considering the work of other investigators, in dissociating between facts discovered by them and hypotheses put forward in explanation. On page 120, second paragraph, the author states that Dr. Jeffries "has shown that with metals in general the cohesion of the amorphous phase equals that of the crystalline phase," etc. Much as I admire the work of Dr. Jeffries, it is a fact that he has not shown experimentally that the amorphous phase exists, neither has he shown any dissimilarity in the properties of the two phases. What Dr. Jeffries has done is simply to postulate, along with other thinkers, that the amorphous phase exists and then, by further hypotheses, to deduce a dissimilarity in the properties of the two phases.

I write this in no hypercritical spirit, but simply with the desire to emphasize that little progress can be made in our attempt to put this subject on a sound basis unless we do dissociate facts from theories. This particular aspect of matters becomes very important indeed when one contemplates the very important new facts concerning metals, particularly aluminum, brought out in a paper by Dr. H. C. H. Carpenter, F.R.S., and Miss Elam, given in July before the Royal Society in London. They have been able to make tensile test-pieces consisting of single crystals and to explore their properties to a considerable extent. This new evidence, in the writer's opinion, indicates that the amorphous theory, so ably handled by many of our metallurgists and physicists, must be reconsidered—at any rate, many of the minor hypotheses concerning the properties of crystals and amorphous films upon which the amorphous theory was based are now shown to be untenable.

This subject, as I have said above, is of great industrial importance, and it is to be hoped that the author and other investigators will not let the matter rest until we have actually provided sufficient data for a really satisfactory visualization of the mechanism and effect of cold work upon metals. W. H. HATFIELD.

Sheffield, England.

Midwinter Meeting American Institute of Mining and Metallurgical Engineers

Dr. Bancroft Presents the First Institute of Metals Lecture—Important Papers and Animated Discussions on Manufacture of Fine Steel—Quality of Steel in Its Relation to Subsequent Use Also Considered—Arthur S. Dwight the New President

IN ACCORDANCE with custom, the American Institute of Mining and Metallurgical Engineers met Feb. 20 at the Engineering Societies Building in New York City for the midwinter meeting. Technical sessions occupied the mornings and afternoons of the first three days of the week, simultaneous meetings of various sections being the rule rather than the exception. Thursday was spent in a very enjoyable, well-directed and all too brief tour of various industrial plants at Harrison, Carteret, Chrome and Perth Amboy, N. J.

Arthur S. Dwight, widely known throughout the Rocky Mountain region as a lead metallurgist and in late years as the "man behind" a successful sintering machine, made his début as president of the Institute at the banquet held Wednesday evening, Feb. 22. As a measure of the interest manifested at all the meetings, it may be stated that the banquet attendance fell but a little short of the record number. Other social functions —smoker, dances, receptions and excursions—filled the time of the members to overflowing.

Institute of Metals Lecture

To our readers, perhaps the most interesting event was Dr. Wilder D. Bancroft's lecture on "Colloid Chemistry and Metallurgy." It was the first of a proposed series of annual lectures. Judging from the attendance and the enthusiasm displayed, the directors of the Institute of Metals Section have embarked upon a program which will have important and far-reaching effects.

Critical Commentary on Amorphous Theory

Defining colloid chemistry as the chemistry of bubbles, drops, grains, filaments and films, Dr. Bancroft immediately passed to a critical examination of Beilby's theory of films of amorphous metal. In fact, throughout the discourse the lecturer took the attitude of a skeptic and pointed out that many of the things of which metallurgists and metallographers talk rather glibly are things which may have been postulated to account for certain experimental results, and with actual proof either non-existent or at best very meager. He took the view that the advocates of Beilby's amorphous metal hypothesis have made an extraordinarily good case with no facts behind them, while the dissenters have never challenged their opponents' premises. Even though it may be true that direct proof of amorphous metal at crystalline boundaries may never be had, there is no reason for accepting it without question in view of the fact that amorphous metal is difficult to form, and being an unstable phase, it will easily revert to the crystalline and stable condition.

Beilby advanced his theory to explain the strengthening of metal by cold-work, but high strength electrolytic copper can be deposited with high current density, and it certainly is not amorphous. Beilby's reasoning seems to be this: "Glass is amorphous and brittle; therefore an amorphous material is always harder and more brittle than the corresponding crystalline aggregate," of course an absolute *non sequitur*. Cold-work is supposed to produce fragments of crystals too small to be crystals. However, it has been found long ago that electroplated copper 3 to 5 millionths of a millimeter thick has the properties of massive copper, and Dr. Bancroft doubts whether cold-work could produce fragments of this size. In fact, the lecturer feels that the properties ascribed to amorphous metal are more likely to be properties of an aggregate of extremely fine crystals.

As an instance of the metallographer's tendency to take things for granted Dr. Bancroft cited the belief in two diagrams for steel. The conclusion that cementite is the metastable state at room temperature is derived from bad reasoning from inadequate examination. The evidence is this: (*a*) Graphite is the stable phase above 1,000 deg. C.; (*b*) quenched gamma iron containing carbon produces graphite on annealing. Now (*a*) says nothing about the stable phase below 1,000 deg. C.; and as to (*b*), it is possible that graphite is intermediate to the final stable compound Fe_3C.

Solid Solutions

Jeffries and Archer's writings on hardening by slip interference appeal to Dr. Bancroft as the "best formulation of the causes of hardness we have ever had" and a distinct step forward. He expressed himself as being personally much delighted by their explanation of the hardening of duralumin and martensite. They were also on sound ground in insisting that Fe_3C does not dissolve in austenite as such—it is not necessary that it should. Bearing on this point, it should be remembered that the copper-tin equilibrium diagram indicates a series of solid solutions passing through the compound Cu_3Sn, and it is orthodox to say that some of these solutions contain the compound. However, it is possible to produce the compound Cu_3Sn, and it will not go into solution in bronzes; are there two different kinds of Cu_3Sn? As a matter of fact, modern metallographists play fast and loose with compounds and solutions, postulating them everywhere. There are six of them already in brass, and maybe there will be more if we do not own up to our ignorance of the essential structure of many things we see under the microscope.

However, it is very necessary that we should know more about the state of aggregation of alloy components. Take the familiar case of thoria and tungsten. If a fine thoria powder be shaken up with coarser tungsten particles, the fines coat the grains rather than accumulate in the voids and a composite briquet is therefore a poor conductor. Alloys between two metals, *A* a conductor and *B* a non-conductor, will naturally have electrical characteristics depending upon whether *A* is dispersed

in *B*, *B* is dispersed in *A*, or whether both metals are continuous and interlace. Yet discussions of conductivity of a series seldom mention this essential point.

State of aggregation of inclusions in steel is apparently of great importance to its endurance under alternating stress. Now is this generally true for other alloys? An increased endurance in metal would be a tremendous advance in metallurgy, and it therefore behooves us to investigate whether it is possible to make clean metal, and whether it is possible to make it commercially.

Corrosion Resistance Due to Surface Films

Colloid chemistry should throw much light upon the corrosion riddle. It is doubtless a hopeless task to produce an absolutely non-corrodible metal—even platinum is probably covered with an oxide—but it is necessary to make metals which corrode only to a limited extent. From its chemical behavior, metallic aluminum would be predicted to be perfectly useless, yet when exposed to ordinary service conditions it becomes covered with a coherent protective film which effectively slows down subsequent action. Nickel also forms a protective film; iron does not. What is the reason for the difference? Measurements of electromotive force are not very informing, since they give only the "tendency" for corrosion and since actual occurrence is the essential point. Thus all the bronzes have e.m.f.'s which lie between tin and copper and have a "tendency to corrode" more than copper but less than tin. As a matter of fact, if a certain group of brittle bronzes, containing 40 to 80 per cent tin, are made anodic in salt solutions, they stand up in a surprising manner, simply and solely because they immediately build up a film of stannic oxide which is coherent and protective. If we knew more about this film we might be able to put metallic tin into such a condition that it, too, would acquire it, whereupon a great boon would be conferred upon the canning industry. Similar studies would tell why copper-bearing steel corrodes less than copper-free steel in the atmosphere, but more rapidly in ground waters.

Electrometallurgy and colloid chemistry have many points of contact. If the electrolyte contains some substance which is absorbed by the metallic deposit, crystals of the latter cannot grow. For this reason, glue has made possible electrolytic lead refining; without glue, the lead is deposited as lovely but useless lead crystals; with it, a dense coherent deposit occurs. Similarly in electroplating. A burnished copper deposit can be taken directly from the tank; unfortunately it costs a little more than to do it the old way. Again, colloidal solutions, or, rather, peptized suspensions, are good things to avoid in electrometallurgy. As instances, the operating temperatures in sodium or aluminum furnaces must be above the melting point of the metal, yet below the temperature where the metal is peptized in the bath, a range which is extremely narrow. If the bath overheats, the metal "fogs," goes to the anode and burns.

Fine Steel From the Acid Open-Hearth

A series of very important papers relating to quality metal were presented before the Iron and Steel Section meetings, drawing forth an animated discussion skillfully directed by the chairman, Mr. Stoughton. Principal among these was "Acid Open-Hearth Process for Manufacture of Gun Steels and Fine Steels," by W. P. Barba and Henry M. Howe, the long-awaited report of work done during the war by the committee on steel ingots, National Research Council.

In summarizing the paper, Colonel Barba said that while the paper is complete in its discussion of principles, many of the almost numberless details of application have not been mentioned. Indeed, many of these details could with extreme difficulty be described—they must be acquired by personal attendance and constant observation on the furnace and pouring platforms. Roughly, half the paper is given over to a description of an adequate furnace and its manipulation, and the remainder to correct pouring practice. It is of first importance to have an adequate furnace—a furnace which will produce and withstand the high temperatures necessary for the reactions going on in the bath. Given this essential implement, one should select the raw materials carefully (having in view the uses for the final product), he should melt hot, refine hot and pour cold into ingots of proper size and shape (again having in view the uses to which the final product is to be put).

If the word "dirt" be used to denote various impurities and inclusions in steel which adversely affect quality steel, "dirt" occurs in two forms—"chemical dirt," the uniformly distributed reaction products, and "mechanical dirt," the occasional and fortuitous particles of foreign materials acquired from the containers. It is very easy to distinguish between these two kinds of dirt. Many American steelmakers have the necessary knowledge, skill and will to reduce all dirt to a minimum, but these same producers must educate the American purchaser to the point where he will appreciate the actual economy in paying the necessary high price for clean steel for special uses. Many consumers do not know that their rejections on final inspection would cease to worry them if they started with the proper metal. Others who want especially good steel for certain purposes do not know it can be had.

Pouring Practice

A visiting English metallurgist, Harry Brearley, was given a warm welcome when he commented upon this paper—especially as regards pouring practice. He emphasized that the temperature in the mold, rather than the temperature in the ladle, was that which was responsible for crystal growth and the physical excellence of the ingot. Thus it is easily possible to "pour cold" with a thin slow stream of very hot metal. Furthermore, it is easiest to judge the temperature by observing the top surface of the metal rising in the mold: it should freeze into a distinct crust and appear like a broken film of cream floating on milk. In Mr. Brearley's opinion, one of the important advantages of bottom casting was the ease with which conditions in the mold could be observed. Somewhat counteracting this was the undoubted fact that bottom-cast ingots ordinarily contained more dirt picked up from the runners. His firm minimized this by extreme care in preparation of molds and by cleaning them with a powerful vacuum cleaner immediately before pouring.

Another advantage of bottom-casting is that the method permits the mold to shape the ingot. When top-casting, the impact of the stream of hot metal always produces more or less commotion in the upper surface. If the flow of metal were stopped at any time and the top surface be examined, it would be found that there would be a thin fringe of metal ("swirl envelope") heaped up and chilled against the side of the mold. This continually formed swirl envelope is the real mold. It is always badly oxidized; the carbon in the advanc-

ing hot steel reduces the oxide partially, forming small quantities of gas bubbles close to the surface. These are later filled with rather impure mother liquor, squeezed into them by the solidifying primary crystals of purer metal, and can be strikingly shown by a sulphur print of a split ingot.

Flakes and Woody Fracture of Nickel Steel

Since the paper by Barba and Howe described the correct manufacture of nickel steel, Haakon Styri recalled the war-time trouble with flakes. In some plants it was observed that their first heats, made by addition of shot nickel shortly before tapping, were accepted. Only when they began using nickel scrap did flakes appear, and one explanation of the cause of flakes was that nickel steel was so much more viscous than carbon steel that its refinement was correspondingly difficult. Colonel Barba pointed out, however, that if the temperature of the furnace in the refining stage is as high as it should be, carbon steel and nickel steel act exactly alike; any difference of viscosity at this temperature is unworthy of mention. In his experience it was entirely immaterial when and how nickel was added—economy and convenience were the only considerations; indeed, for many years most acceptable gun steels were made by adding nickel oxide to the charge. Brearley also denied that nickel steel was necessarily full of slag inclusions, despite wide belief in the myth. To be clean it must be made right. Furthermore, its inherent toughness caused the inclusions which were contained to become very evident in a fracture. It ought to be axiomatic that an inclusion is a discontinuity in steel, and that discontinuities do not show until the metal is deformed. A metal which is brittle, for instance, will show a sharp break despite an actual fibrous or laminated structure. If wrought iron could be made brittle, it doubtless would lose its characteristic fracture. On the other hand, nickel steel, like normal wrought iron, is so tough that it must deform very considerably before fracture, and any discontinuities are sure to be sought out and much magnified into the appearance of fibers before ultimate rupture.

When introducing his paper on "Effect of Sulphur and Oxides in Ordnance Steel" W. J. Priestley of the U. S. Naval Ordnance Plant wished to distinguish between true flakes occurring in nickel steel made in the electric furnace and similar defects in open-hearth metal. The latter always contain slag inclusions, while a true flake has none. In his experience the microscope can indicate whether a gun steel is likely to develop woody fractures; forged open-hearth steels containing perhaps 0.04 per cent sulphur when examined in longitudinal section will show small round inclusions and much larger particles, elongated and drawn out in forging. It will also show woody fracture and lower ductility (elongation 18 per cent, contraction 40 per cent) when tested tangentially. Electric-furnace steels, properly refined under a carbide slag and with sulphur reduced below 0.015 per cent, show only the tiny round inclusions, tangential specimens will break with silky fracture and show higher ductility (elongation 24 per cent; contraction 53 per cent), results which would be looked upon as very remarkable indeed 10 years ago. Such steels, however, will develop true flakes if cast too rapidly at too high a temperature, chilled below a certain point in the mold, or even cooled too far in forging. Minute radial cracks will then appear near the center of the ingot or forging.

Degree of Reduction in Ingots

Ordnance makers at the outbreak of the war were still working to specifications framed 30 years ago when all heavy forgings were shaped under the hammer. On account of the somewhat superficial effect of a quick blow a reduction of 4 to 1 was required for gun tubes. Meantime the hydraulic press was introduced, so during the war the specification was modified to allow only 2½ to 1 reduction. Colonel Barba expressed the opinion that a ratio of 1¾ to 1 would be quite safe for 6-in. forgings made of best steel and with heavy presses; penetrative effect was not well known, so a greater reduction would be justified for larger pieces.

Degree of reduction has a considerable bearing upon the quality of the finished piece, and correspondingly upon the physical properties of test-bars. There are really three main dimensions to a forging; in a gun tube they might be called longitudinal, tangential and transverse to the direction of extension by forging. Tangential tests are most useful in studying quality of gun tubes, first, because they parallel service stresses, and second, because they best show defects and foreign inclusions. However, Priestley remarked that a tangential test-bar from a tube which had been reduced 7 to 1 would give a percentage contraction little over half that from the same steel reduced only 2½ to 1. To avoid this weakness, the forging should apparently be just sufficient to allow ingot structure to be broken up by subsequent heat-treatment, and yet not so great as to range the inclusions along definite planes. Thus it is that while commercial consideration might dictate that big ingots be used to make small articles, it was not always desirable from a metallurgical standpoint. One might infer from Colonel Barba's remarks, however, that heavy reduction of not too clean steel was most desirable for armor plate, since he observed that he would be suspicious of a plate if a bar cut from face to back would give more than 1 or 2 per cent elongation. He said that to be tough enough to keep shots out, a plate had to be laminated parallel to its face. Priestley, however, observed that there was room for difference of opinion on that point; armor plate made from deoxidized and desulphurized electric furnace steel would possess considerable ductility if tested transversely (from face to back). Such plate, when pierced by a shell, opened at one spot and segments curled back like an orange peel. If plates such as Colonel Barba described were penetrated, the shell seemed to punch out a clean button.

Test for Dirt in Steel

Such considerations led Brearley to propose a test for dirt in steel based upon the ratio of impact strength of longitudinal and transverse bars. If, for instance, an ingot be rolled under controlled conditions into a 5 x 1-in. bar and test-specimens be cut at varying angles to the direction of rolling, it would be noted that the tensile strength was substantially the same in all directions. Figures for ductility were also constant until the angle passed 40 deg., when they would show a drop. Notched bar impact, however, would be highest in a bar cut in a longitudinal direction, but progressively less as the angle increased up to 90. In his opinion the two impact values (at 0 deg. and at 90 deg.) never could be equal; in most commercial steels the ratio is not over one-tenth. However, in fine steel, such as for ball races, it should be at least one-half. He recommended this ratio as a measure of "dirt in steel."

Industrial Research and Patents

A Competent Patent Department Can Aid the Research Laboratory in Examinations Into the Literature and State of the Art, in Charting Lines of Inquiry Not Blocked by Patent Barriers, and in Protecting Embryonic Ideas Pending Their Commercial Development

BY CLAYTON L. JENKS
Patent Attorney, Norton Company, Worcester, Mass.

BUSINESS MEN are ordinarily quick to recognize a new order, but have they grasped the present opportunities offered by research? How many managers of manufacturing corporations know the value of systematic investigations along commercial lines? How many have definite plans for experimental development?

THE FACTORY LABORATORY

The man down in the plant as a rule must lower costs and handle the everyday problems of keeping the plant going. What he most wants to hear is the smooth hum of well-oiled machinery, to know that his work is being done on time and well. The very nature of his work tends to make him conservative; but it also shortens his perspective. He perhaps recalls some earlier financial loss due to misplaced confidence in an invention alleged to be valuable and looks suspiciously upon all inventors and researchers.

Nevertheless, because of the difficulties of maintaining quality and standards in the face of growing competition, and knowing somewhat of the investigations of the more progressive companies, the successful factory manager ultimately establishes an engineering department for developing new machinery and later a laboratory for handling the more scientific problems of the factory. Since the main problems in the factory manager's mind are cost, speed of production, quality and works control, a laboratory developed under factory supervision and representing the gradual outgrowth of the necessity for scientific plant control will reflect mainly the practical side of the work in equipment and personnel. The inventing business is viewed in the light of money returns, and the laboratory men become limited in their activities largely to the problems of correcting factory troubles. Spare time only is spent on research.

The works problems may be of no mean order and require the services of highly technical students, as well as skilled artisans. These laboratory men occasionally hit upon new ideas in the course of their investigations, but for lack of time and resources must carry on their experiments according to some haphazard method. Such investigations must be sandwiched in with routine tasks, and soon the edge wears off of the workers' enthusiasm. Ever-insistent foremen waiting to be shown how to correct their errors keep the research notebook in the desk drawer and the problem is laid aside for less crowded days. Still, if lucky, something good may be developed and the state of the art advanced to the glory of the haphazard inventor and the welfare of his employer, if the half-thought-out invention survives competition and the tests of time.

But such sporadic attempts are not research. Thoroughbred racers cannot do the work of draft horses, nor do the latter win many races. Research must be conducted by research men in proper surroundings and with research equipment. Patent the basic ideas of such laboratory work? It may never be thought of!

THE OLD-FASHIONED ENGINEERING DEPARTMENT

In the engineering department, the chief engineer dominates the inventing business. He is an inventor, made conservative by years of hard knocks. His new machines are eagerly sought, for his work is good. What are his methods? Being an inventor, he is possibly jealous of his pet schemes, intolerant of others' ideas. Surrounding him are embryonic mechanical engineers fresh from college or enthusiastic draftsmen, full of ideas, imaginative, perhaps intolerant too of the "old man's" conservatism. They suggest inventions to the chief, which as originally sketched out are probably poorly designed and not commercially feasible. With a hasty glance over the drawings, the chief turns them down. After a number of such rebuffs the youthful inventor concludes that imagination and vision are unwanted. Yet within some poorly thought out scheme may have been a germ of value, capable of development by the older and more practical engineer; but the scheme is dropped and forgotten. Years later, the engineer, perhaps subconsciously recalling the old idea, reinvents it and finds it worthy of development. He builds his machine for the market and then finds it patented by a rival.

It is almost axiomatic in the patent business that if one man does not invent a certain improvement today, another will tomorrow. The different workers in an art read the same literature, see the same machines on the market and learn of the same requirements of the trade. Is it any wonder that they invent the same things? The man first to the Patent Office is likely to win the field.

When that young man's suggestion was offered, the chief engineer, disregarding the patent situation, refused the idea merely because it was *impractical as then clothed*. A preliminary patent search might have shown that the idea was unprotected by patents, that it in fact found the weak spot in a competitor's armor, that it provided a passage to the market free from patent dominance. A little experimental work, sometimes a mere "paper patent," would have reduced the idea to practice and saved a valuable monopoly.

The amount of property, the wealth of ideas lost by such old methods, is large. With the same organization, the same brains around him, that engineer, by judicially investigating the new ideas, experimenting and modifying, selecting the wheat from the chaff, could produce far greater results. His fairness would bring around him a group of loyal enthusiasts. He, the older practical man, would serve as a balance wheel, the others would furnish the fuel.

"Of what use are these theorizing dreamers, these impractical scientists?" says the practical shop man. That question has probably been asked since Adam and Newton observed the different phenomena connected with the apple. Such a business man would not understand how Kekule's benzene ring formula could be of any practical use, yet most dyemakers do. But the dreamers keep on theorizing in spite of ridicule; they need no defence. Not only will their contributions to science be remembered, but they are fundamental to our modern civilization with its luxuries and comforts.

It must be obvious that real commercial progress calls for systematic research effort, but how make it pay? The answer lies in the solution of the further question: Is the laboratory merely doing the necessary routine factory analyses, solving the problems of quality and production, occasionally hitting upon some new method or product, partly accidentally or because there is a temperamental man in the laboratory who cannot be held down, or is the laboratory working within a well-defined channel, studying its problems from theoretical aspects, and yet keeping practical minded, with its weather eye on the patent situation in every move?

Essentials of a Laboratory[1]

From the experiences of various large laboratories it may be concluded that the company management needs to do but four essential things: Decide upon a research policy, equip a laboratory, appoint a director and give him a definite yearly appropriation. Then—back the research with dollars and patience. The director should not be required to produce remunerative ideas at first, perhaps for several years. The value of his work is cumulative and will increase rapidly as time goes on. It is of absolute importance that the laboratory should be entirely dissociated from the factory departments, yet be kept posted on manufacturing activities. To insure these conditions the director of research should report only to the management and have complete control of his work and expenditures within the stipulated limitations. Above all, he should not have to explain beforehand how a given investigation may lead to commercial results. There is no surer way to kill inventive progress than by requiring such proof. In fact, purely theoretical research, with no practical goal in sight, often leads to the greatest achievements. The original workers with vacuum tubes or high-frequency electric currents surely did not realize the wonderful commercial possibilities in their theoretical studies.

The laboratory should be divided into two divisions: (*a*) for manufacturing control and (*b*) for science, and the men for the two branches carefully selected according to their leanings toward practical or theoretical problems. If the laboratory is housed apart and equipped with a complete manufacturing outfit, its tests may be conducted on a manufacturing scale where necessary without interfering with the production department, which ordinarily has no enthusiasm for the notions of "impractical dreamers."

It is generally impossible to staff a laboratory with a large number of geniuses, but one must obtain well-trained men who have a taste for research. They must be men of imagination, inventors, with enough enthusiasm to keep buoyed up under the criticisms of the shop men. It is also considered a fact that the yield per man increases with the number of men who can co-operate. Most problems are so large as to require the combined efforts of men who are specialized in different fields. Hence each man should be encouraged to be frank and helpful in analyzing his co-workers' problems and in giving the best of his own inventive ideas as suggestions for the others' use. A properly worked out system of awards and recognition will do away with the jealousy and secretiveness so frequently associated with the inventive mind.

Since only a small percentage of the investigations started are likely to be successful, the director should be capable of properly organizing his department and the work, and strive to reduce to a minimum the proportion of unsuccessful cases. Generally the deeper the investigation goes into fundamental facts the greater the chance for success. The choice of research work must be determined by the laboratory men's ideas, and not by the too practical considerations of the management, but of course such work should all fall within certain well-defined lines laid down by the directors of the company.

Interrelations of Patents and Research

Assuming that such a research laboratory has been organized, where is it likely to fail? Often in spending large effort, money and time on ideas already appropriated by others' patents.

Not understanding the nature of patents, with their repetitions, their fine shades of meaning and their ambiguities—all legal problems—many researchers ignore the patents and do not consult this remarkable collection of literature. Yet where could one find a better story of any particular art than in the U. S. Patent Office archives? Others perhaps think of patents as legal barriers tending to prevent research. A patent is a barrier, however, to but a small field. Obviously one of those million and a third U. S. patents cannot stop investigations.

Other laboratory men, like true Americans, naturally abhor monopolies and keenly feel that research should be open, co-operative and always in the interest of the progress of the sciences. Hence, while loyal to his company's welfare, such a man may instinctively object to his ideas being patented.

There are several reasons for taking out patents. From the point of view of the owners of the company, these patents are to serve as defenses in keeping competitors from copying their products, or as offensive weapons to aid in holding a commercial field which the company developed. The laboratory worker surely need waste little sympathy on the leech in business who does no experimental work but spies out the accomplishments of his more progressive competitors and copies their products as closely as he dares. The researcher certainly would not like to feel that his work has gone for naught; that when he has finished his experiments a lazy competitor may appropriate his idea and use it to defeat the end for which he has been working. Patents to prevent such unfair competition are certainly justified. It has always been recognized in civilized countries that one has a right to his discoveries for a limited period of time, provided he keeps his bargain with the public by giving the latter a full disclosure of the invention in return for a short-term monopoly.

On the other hand, one need feel no apprehension

[1] For a clear discussion of this phase of the subject the reader should consult the book "Organization of Industrial Scientific Research," written by Dr. C. E. K. Mees, director of research for the Eastman Kodak Co., published by the McGraw-Hill Book Co., New York.

that the patent covering his particular accomplishment will prevent the progress of the science, since any progressive company which stands on its own feet, does its own experimenting and builds up a business on its own good will and prestige is never seriously handicapped by patents taken out on the other man's work. A patent validly covers only what is new. All that is old belongs to the public. Hence, in view of the large amount of known information preceding that particular piece of laboratory investigation, the patent obtained will not ordinarily be of large scope, but will serve merely to protect the particular field within which the investigation has been made. The competitor obviously is not prevented from developing other fields.

The laboratory worker might better look upon a patent as a written disclosure of a piece of research accomplished and leave the question of legal barriers for the patent attorney to decide. From a more personal viewpoint, the patent stands somewhat as an official certificate of the government that a given person has developed something new, that he has added to the sum total of scientific knowledge, that he is wide awake, progressive, a leader and not a follower.

What Is Patentable?

"What is patentable?" is a question which the research investigator should not attempt to answer. That is one weakness in the average laboratory. A scientist is likely to be overmodest and belittle the results of his work, or, rarely, the man in charge may not be enthusiastic for ideas which he did not personally develop. Again, many ideas when first suggested seem impractical. They probably are, as first thought out, and cannot be made workable without a certain amount of investigation and study. Nevertheless such embryonic ideas may be basically valuable as patent rights. If the laboratory director does not take up the suggested idea, it may lie dormant for years and then perhaps be forced to the front through some change in the commercial field. By this time one's competitors have reached the same stage of commercial development and it is more than likely that the idea will be developed and patented by an outsider.

It is the same with questions of interpretation of a patent. The laboratory man, not being skilled in patent matters, either considers a patent as a barrier to further work or ignores its fine points and may conduct his own work along lines which are prohibited. A patent expert, having a general survey of the whole patent field and knowing the commercial value of patent rights, is in far better position than the laboratory head to decide as to the patentable merit of the laboratory work.

Patent Department

In order that the laboratory may make the most of its opportunities, it must be alive to the patent situation; hence it must have a specialist on its staff or at its call who knows the value and scope of patents, who can advise on questions of infringement and obtain protection for the new ideas. In no way can this be better accomplished than by establishing a patent department. The scope and nature of this department obviously will depend on the size of the company, its research program and questions of finance. Let it be said here, however, that a company large enough to carry on research is too large to neglect its patent protection. This department may be headed, and preferably, by a patent attorney of experience and vision, who is located at the plant. For the smaller company, the department may be run by a younger man, but only under the supervision of an older attorney who is acquainted with corporate problems and who can develop an adequate system. Essentially, the department head must have intimate contact with the inventors and know their work and their problems. He should have full access to the laboratory files, attend laboratory conferences and otherwise be in position to follow closely not only what is being done but, perhaps more important, know what it is proposed to do. In addition, a thorough understanding of the company's program, its sales activities, its manufacturing problems, are all essential to his success in helping the laboratory's work.

Such a department head, or his supervising attorney, must not merely do what he is told to do, as must the outside attorney who has no personal interest in the company and is only called in when some one at the plant, unskilled in such matters, happens to think of the patent situation. The corporation attorney, on the contrary, shoulders the full responsibilitiy of protecting the company's patent interests. For example, the department head may have to rewrite a piece of advertising to correct an improper use of a trade mark; he censors the printing of new labels; he studies competitors' catalogs and their advertising and otherwise keeps a systematic watch for infringements; he collects old records and proofs and establishes a model room showing the historical and inventive progress of the company, which may be invaluable as legal evidence in some future controversy; he is ready with advice to aid the engineer or the research director in choosing his lines of development; he may establish a suggestion system or other method of rewarding employees for their ideas; in fact, he must keep in touch with every phase of the company's business which spells progress.

Other Functions of a Patent Department

Other functions of the patent department involve blazing the trail and finding new paths for development. This requires vision and knowledge of company methods and policies, as well as the public's wants and competitors' activities. Perhaps some basic patent in a new field may be obtained. Every company is being constantly importuned to buy patents. This may in fact be such a large problem as to take much of the department's time. For example, one large corporation receives perhaps a thousand such letters in a year. It requires judgment of patent values as well as of commercial and manufacturing problems to know when not to turn down such offers. Again, the corporation attorney may see the possibilities in obtaining a license under some basic patent held by a competitor, or, on the other hand, in expanding the commercial development of a new field which requires extensive advertising by granting licenses to competitors, as has been done with such basic patents as control the electric lighting field. Another duty of the department is to seek the loopholes in the claims of a competitor's patent and advise the laboratory how to get around the apparent barriers. Such a task needs a man acquainted with corporate methods, full of vision and inventive imagination, a lover of research as well as one versed in patent law and capable of understanding and using discriminating English with all its finer shades of meaning.

When a new research idea is proposed to the patent department, one of the first questions is, Whose field is it? A public common, or land fenced in and culti-

vated, or virgin country? A preliminary patent search tells. The specialist hunts out all the related patents, digs up pertinent scientific literature and reports to the research director on both patentability and infringement. If the scheme is broadly new, all is clear sailing. Usually patents and publications tell of others' efforts along the same line—perhaps failures, perhaps success. What is the situation? If no patent claims are found to be infringed, one is fortunate. Otherwise a path of research must be mapped out, carefully turning this way to avoid a line of patents and that way to meet practical considerations of manufacture and market. This can be done only by patient study by both research and patent departments combined.

Two courses are open for securing patent protection on the new idea: To file a paper patent or to develop the idea by experimentation. Both have their advantages, but the experimental work should not be delayed if the patent is filed first. The original inventive idea may be crude and not acceptable to the manufacturing department. Yet if it can be made to work, the attorney asks no more, if he decides to file an application without delay. (Incidentally, if there is no patent department, the laboratory seldom thinks to take up the basic idea with an outside attorney at this stage.) The draftsmen take the crude idea and with the inventor's help draw up a design sufficient for patent drawings. A patent application is filed and the important date, in the eyes of the Patent Office, of completion of the invention is established. The laboratory or engineering department may then, at its leisure, work out the details of the scheme, design an appliance, build it, test it and get it ready for the market. When practical and complete, if the final product is radically different from the one filed in the Patent Office, a new application may be filed on the details of novelty over the first crude scheme; or the old application, if it has not gone to patent, may be abandoned in favor of a new one. The point is that the application pending in the Patent Office during this period of experimentation has given a certain degree of protection ordinarily sufficient to preserve the monopoly.

Department Problems and Equipment

When a patent department is established for a corporation which has never had such facilities, the attorney first finds a degree of suspicion and lack of co-operation which is surprising. This is due largely to the fact that previously the plant has been run on the theory that secrecy was the best policy; but those methods are fast becoming obsolete. However, he must advertise the value of patents and of his services to the inventors and possibly to the company management. The attorney will also find that the value of his services to the laboratory is directly in proportion to the degree of contact which he maintains with the inventors, either personally or through a personal representative. Periodical intimate talks with the different inventors are necessary. He must attend the laboratory conferences. A conference between investigator and the attorney and a short search through the patents and literature to find the related art will put the former on the proper line of attack with the least waste of time and effort.

A necessary part of the patent department's equipment is a patent file containing all of the U. S. patents and the available foreign patents relating to the art, as well as an accessible and adequate library. The number of patents relating to a given field is sometimes surprising; for example, there are over 12,000 U. S. patents relating to the abrasive industry. Such a file is particularly necessary these days owing to the handicaps under which the U. S. patent examiners work and their inadequate resources. Furthermore, the U. S. Patent Office takes no responsibility in granting an improper patent; the patent department must therefore see that its patents actually protect. Hence the specification writer must have a full survey of the field before him when he draws his claims and when he reports on questions of infringement.

The patent file serves an equally useful purpose for preliminary patent searches to advise the laboratory of the related art before experiments are started. The expense of having such searches made in Washington would of course be far greater than the cost of such a file. Moreover, since but a small percentage of the patents granted ever get into commercial use, and yet many of them are not only practical but possess ideas of merit, it is desirable to go over the disclosed art occasionally to bring the old ideas to the attention of the experimental worker.

It will be found that the patent department handles much chaff when considering the laboratory inventions. One large corporation finds that about one-third of the ideas proposed are of patentable value. I have found that the percentage may run considerably lower. It it not wise to ignore the simpler ideas, since these may ultimately develop into practical schemes.

As to the practical application of the outlined system, the following facts may be of interest: One large corporation within my knowledge originally filed less than four patent applications per year. After a patent department had been established it was found that the same body of workers produced seventeen patentably valuable ideas in three months' time. Another and larger corporation with a progressive research laboratory filed twenty-eight applications in one year before the patent department was established. After two years of patient work on the part of the patent attorney in studying the field and searching out the inventions, about fifteen applications were filed each month. Where such investigators had previously limited their activities largely to factory problems, the stimulus due to the patent department's activities helped to expand the laboratory's viewpoint and led to the development of commercial products which might never have been produced.

Vision

In conclusion, it might be well to state that one of the strongest patent monopolies in this country is held by a company which has in effect merged its engineering and patent departments and placed the research and inventive functions of the organization under the control of an executive committee for experimental work, made up of members of both departments. A member of this committee recently said of their new policy:

"It will not be possible to sell the old line of machines, as the users are supplied for years to come; hence it is now necessary to invent and design new machines so much better and cheaper than the old ones that it will be an economy for users to scrap the old and purchase the new."

With such vision, the engineers are eagerly pushing ahead to bigger fields and their company cannot help but succeed. Enthusiasm always wins.

A Study of the Saturated and Unsaturated Oils From Shale*

Results of Experimental Work on the Composition and Properties of the Lighter Fractions and Heavy Undecomposed Residues Resulting From the Pyrolytic Treatment of Crude Shale Oils

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IN PREVIOUSLY published papers on saturated and unsaturated oils from shale[1,2] the author has presented data which indicated the following facts relative to the saturation and decomposition of certain crude shale oils: As obtained from plant and laboratory retorts, these oils consisted of 12 to 40 per cent of constituents (saturated compounds) unabsorbed by cold concentrated sulphuric acid and 60 to 88 per cent of materials removed by treatment with this acid. The crude oils decomposed readily on distillation at atmospheric pressure and formed coke, gas and lighter oils containing 15 to 83 per cent more saturates by volume than the original oil. The decomposition occurred during the distillation of the heavier fractions, was greatest for oil which had been retorted with steam, and was practically completed by one distillation. The lighter fractions were more highly saturated and the saturation diminished as the specific gravity of the fraction increased. Distillations with steam, with inert gases, and under diminished pressure tended to prevent the cracking, but the oil obtained in all cases contained a lower percentage of saturates. The statements which concern the decomposition of crude shale oils and the effect on saturation are based on experimental work with five different oils from Colorado, Utah, and Nevada shales.

FURTHER STUDY ON THE PYROGENETICS OF SHALE OILS

The effects of the decomposition as shown by these oils may be looked upon with favor by the refiner, since cracking improves the quality of the oil and increases the quantity of gasoline, which is the most highly saturated portion; but new problems are presented to the oil chemist, since an increase in saturation as a result of decomposition at atmospheric pressure is at variance with the usual conception of the cracking of petroleum oils. In the former papers it was suggested that this strange phenomenon might be caused by the decomposition of heavy unstable unsaturated compounds, but that more experimental evidence as to the composition of these materials was desirable. From both practical and theoretical standpoints it appears of interest and importance to determine to what extent this behavior is true of other crude shale oils, and to study the lighter fractions obtained by cracking and the heavy undecomposed materials with the hope of ascertaining more regarding the cause of this unusual example of pyrogenetics and of increasing our knowledge concerning the composition and properties of the constituents involved in the decomposition. It is the purpose of this paper to present the results of additional experimental work along these lines.

DECOMPOSITION OF CRUDE SHALE OILS ON DISTILLATION

Crude shale oils from other fields (see Table I) than those studied in the former papers have been examined to determine the amount of decomposition on distillation and the effect of the cracking on the content of saturates and nitrogen. The Scottish oil was produced in the plant of the Oakbank Oil Co., Ltd., and the Norfolk oil in an experimental retort on the property of the English Oilfields, Ltd.[3] The other oils were obtained by distillation in laboratory retorts operated at moderate temperatures without steam using shales representative of localities in the fields mentioned in Table I.

A portion (50 or 100 c.c.) of each of the crude oils was distilled from a Pyrex distilling flask the capacity of which was double the volume of the oil used. The distillation was conducted at the rate of about one drop a second until the formation of a hard coke. The water was measured by volume. The weight of the coke was obtained as the difference between the weight of the empty flask and the weight of the flask and contents after the distillation. The crude and once-run oils were measured both by volume and by weight. The percentages of gas were calculated by difference.

Tests were made on the crude and once-run oils for gravity and saturation by the methods used for the oils previously studied.[4] Six of the oils of most varied nature were analyzed for nitrogen both before and after the distillation. In making the nitrogen determinations the oils were first washed five times with an equal volume of hot water to remove soluble nitrogen compounds. The oils were then kept warm for 24 hours to insure a rather complete separation of the water. The nitrogen analyses were made by the following modification of the Kjeldahl-Gunning method: A sample of the oil (2 to 3 g.) is digested in a 650-c.c. Kjeldahl flask with 10 g. potassium sulphate, 0.3 g. anhydrous copper sulphate and 45 c.c. of 96 per cent sulphuric acid. After the oil has been completely decomposed, the flask is cooled and 300 c.c. of water added. The flask is again cooled and a small piece of paraffine introduced to prevent foaming. The usual excess of sodium hydroxide solution is run gently down the inside of the flask, a few pieces of zinc shot are immediately dropped in and the distillation is then made in the usual manner. The ammonia is distilled into 0.1 *N* sulphuric acid and the excess titrated with 0.1 *N* sodium hydroxide, using

*Contribution from the Research Laboratories of the Colorado School of Mines, Golden, Col.

[1]Read at the October, 1920, meeting of the Colorado Section of the American Chemical Society. Abstracted in *Shale Review*, November, 1920, p. 6.

[2]CHEM. & MET. ENG., vol. 24, p. 876, May 18, 1921.

[3]The author is indebted to the above mentioned companies and to President V. C. Alderson of the Colorado School of Mines for the samples of shale and oil from England and Scotland.

[4]CHEM. & MET. ENG., vol. 24, p. 878.

TABLE I—DECOMPOSITION OF CRUDE SHALE OILS ON DISTILLATION

Crude Distilled	Products Obtained by Distillation of Crude Oils—Percentage by Weight— Water	Oil	Coke	Gas	Changes Produced by Distillation of Crude Oils— Gravity Crude	Gravity Once-run	Saturates Crude Per Cent	Saturates Once-run Per Cent	Nitrogen Crude Per Cent	Nitrogen Once-run Per Cent	Add't'l Sata. Per Cent	Loss Oil Per Cent	Loss Nitrogen Per Cent
Utah No. 1	0.2	80.9	16.5	2.4	0.939	0.888	26.5	40.0	....	....	7.7	18.9	....
Nevada	0.1	95.0	3.4	1.5	0.877	0.851	41.2	58.8	0.31	0.20	16.4	4.9	35.5
Colorado (plant)	0.3	89.5	8.4	1.8	0.920	0.904	16.0	30.0	1.41	1.16	11.3	10.2	17.7
Colorado (laboratory)	0.2	94.0	4.4	1.4	0.889	0.870	25.1	36.4	....	....	9.8	5.8	....
Utah, No. 2	0.3	83.0	10.4	6.3	0.917	0.8745	23.0	45.6	1.45	1.04	16.7	16.7	28.2
Wyoming	0.3	93.5	4.1	2.1	0.899	0.868	20.0	36.0	....	....	14.9	6.2	....
Kentucky	0.0	91.1	6.2	2.7	0.919	0.899	30.0	40.5	....	....	7.7	8.9	....
California	0.0	94.5	3.4	2.1	0.926	0.912	41.0	43.5	0.45	0.41	0.7	5.5	8.8
Scotland, Oakbank	0.07	95.24	3.76	0.93	0.876	0.858	38.0	57.2	0.85	0.65	17.6	4.7	23.5
England, Norfolk	0.1	87.2	8.2	4.5	0.992	0.970	7.0	14.6	0.88	0.81	6.0	12.7	8.0
England, Blackstone seam	0.2	78.0	12.1	9.7	0.986	0.852	8.8	55.0	*	*	40.8	21.8	....

*Unfortunately, our supply of this crude oil was not sufficient for the nitrogen analyses.

TABLE II—YIELD, GRAVITY AND SATURATION OF PRIMARY AND SECONDARY GASOLINE

	Colorado Crude Retorted at Low Temperature Primary	Colorado Crude Retorted at Low Temperature Secondary	Colorado Crude Steam Retorted Primary	Colorado Crude Steam Retorted Secondary	Colorado Crude Retorted at High Temperature Primary	Colorado Crude Retorted at High Temperature Secondary	Nevada Crude Primary	Nevada Crude Secondary	Wyoming Crude Primary	Wyoming Crude Secondary
Yield, per cent	20.3	5.1	13.6	10.5	29.0	2.7	2.62	5.83	26.5	8.0
Gravity	0.783	0.779	....	....	....	....	0.820	0.785	0.787	0.790
Saturation, per cent	51.0	54.0	50.0	50.6	52.4	57.0	58.8	60.2	48.2	49.8

cochineal as indicator. These analyses were all made in duplicate and where the results did not agree within the limits of experimental error the determinations were repeated until the correct percentages were assured.

The results obtained by the distillation and analyses of these crude and once-run oils are given in Table I, which also contains for convenience similar data for four of the Colorado, Utah and Nevada oils previously studied (the first four oils in Table I). The "additional saturates" of Table I are the new saturates formed by cracking and are calculated from the volume of the saturates in a 100 c.c. of crude oil and the volume of saturates in the once-run oil obtained from 100 c.c. of this crude, by subtracting the first volume from the second. The percentage given is the amount of saturates formed by cracking expressed in percentage of the original crude oil. The "loss of oil" is the sum of the percentages of gas and coke, and does not include the water, since this was present in the crude oil and not formed by the decomposition. The "loss of nitrogen" is the total nitrogen lost in coke, gas and in the water-soluble compounds of the once-run oil, expressed in percentage of the nitrogen present in the crude oil.

Discussion of the Results in Table I

From the data in Table I it is evident that all the crude oils tested decomposed to some extent on distillation and that the decomposition was accompanied by an increase in saturation and a decrease in nitrogen content. There is, however, quite a wide range in the amount of these changes. The California oil, which in many ways resembles petroleum, is little changed in gravity, saturation or nitrogen content and forms but 5.5 per cent of gas and coke, while the Kimmeredge oil from the Blacktsone seam decreases 0.134 in gravity, has an increase of 40.8 per cent in "additional saturates" and forms 21 per cent of gas and coke. These two oils are probably extremes, while the others, which lose 5 to 19 per cent as gas and coke, decrease from 0.016 to 0.050 in gravity, yield 6 to 17 per cent of "additional saturates" and lose 8 to 35 per cent of the nitrogen, are probably more representative of shale oils as a class. However, crude shale oils from different strata in the same locality may vary in these respects, but at present no data are available on this question. It is also known that crude oils retorted from the same shale under different conditions vary considerably in degree of decomposition.[5]

[5]Chem. & Met. Eng., vol. 24, May 18, 1921, p. 878, Table III.

It is evident by a comparison of the results given in the last part of Table I that there is no quantitative relation between the "loss of oil" and the "additional saturates" or the "loss of oil" and the "loss of nitrogen." But where the percentage losses of nitrogen are high (17 per cent or more) there is a large yield of "additional saturates" (11 to 18 per cent) and where the nitrogen losses are low (8 per cent) the "additional saturates" are smaller (6 per cent or less). This suggests that the "additional saturates" may be formed by a decomposition of unstable nitrogen constituents. The rôle of the nitrogen compounds in the decomposition deserves consideration because 2 per cent of nitrogen in the heavy unstable materials, combined with carbon, hydrogen, and possibly some sulphur to make molecules as high in molecular weight as these materials probably are, would account for the greater portion of the unstable materials. Molecular weights such as $C_{21}H_{41}N$ require but 3 per cent of nitrogen. Many investigators have noted that petroleums high in nitrogen are easily decomposed by distillation at atmospheric pressure.[6] It is possible that this instability may be caused by the nitrogen constituents and that saturation tests before and after decomposition would show an increase in saturation similar to that of the shale oils. The stability of the once-run oils proves that they contain lighter nitrogen compounds not easily decomposed.

Light Oils Obtained by Cracking

Some information concerning the oils produced by cracking at atmospheric pressure can be gained by a study of the lighter fractions of both the crude and once-run oils, since the latter contain the light oils formed by the decomposition. For a number of the crude oils under investigation the percentage, gravity and saturation of the fractions to 410 deg. F. were determined. For the oils given in Table II these values were determined and then this fraction (primary gasoline) was excluded, the remaining fractions composited on distillation and this once-run composite distilled to 410 deg. F. The second light fraction thus obtained (secondary gasoline) consists of oils formed by cracking. The gravity, saturation and percentage of the secondary gasolines are tabulated in Table II with similar data for the primary gasolines. Table III gives similar data for other oils, but here the primary gasoline

[6]Mabery, *J. Soc. Chem. Ind.*, vol. 19, p. 504; *J. Am. Chem. Soc.*, vol. 41, p. 1691. Richardson, *J. Soc. Chem. Ind.*, vol. 19, pp. 122 and 123. Coates and Best, *J. Am. Chem. Soc.*, vol. 25, p. 1151. Peckham, *J. Frank. Inst.*, vol. 146, p. 45. Salathe, 13th Report Cal. State Mineralogist.

is included with the secondary as "total" gasoline and the distillation of one of the crude oils was made with steam. The yields are given in percentages by volume of the original crude oil.

Discussion of the Results in Tables II and III

The primary gasolines from the different shale oils vary in quantity (2.6 to 26.5 per cent) and saturation (42.4 to 60.0 per cent). For oils from the same sample of Colorado shale retorted under different conditions the quantity and saturation of the primary gasoline fraction are lowest for the steam retorted oil (13.6 per cent and 50.0 per cent respectively) and highest for the oil retorted at higher temperatures without steam (29 per cent and 52.4 per cent respectively). For the secondary gasoline the quantity and saturation vary with the field from which the shale was obtained and the quantity is also influenced by the method used in retorting. For the Colorado shale oil mentioned above this quantity was 2.7 per cent where the retorting decomposition was greatest and 10.5 per cent where the retorting decomposition had been diminished by the use of steam. For each shale oil tested the secondary gasoline fraction has a higher saturation (0.6 to 9.0 per cent) than the primary fraction. In other respects these light oils appear to be very similar in composition and properties. This might be expected, since both are decomposition products, the primary gasoline being produced by cracking in the retort and the secondary by decomposition in the still. Both are cracked gasolines and are about equal in quality. Since the prevention of cracking diminishes the yield and does not improve the quality of the gasoline, there is no reason as far as gasoline is concerned for the prevention of cracking either in the retorting of the shale or in the distillation of the oil.

TABLE III—YIELD, GRAVITY AND SATURATION OF PRIMARY AND TOTAL GASOLINE

	Utah Crude		Utah Crude First Distillation With Steam		Oakbank Crude	
	Primary	Total	Primary	Total	Primary	Total
Yield, per cent	13.6	26.2	13.5	21.2	12.0	15.75
Gravity	0.800	0.795	0.807	0.810	....	.....
Saturation, per cent	42.4	51.7	43.2	46.8	60.0	65.6

Unstable Materials of Crude Shale Oils

Since the decomposition which occurs during the distillation of crude shale oils is greatest for the heavy fractions and is diminished by distillations with steam, the unstable materials should be found in large quantities in the heavy residue remaining after the lighter oils have been removed from the crude by distillation with steam. Two samples of the heavy undecomposed materials were prepared in this manner. The first was obtained by distilling 4,000 c.c. of a crude Colorado shale oil to coke with steam and reserving the last fraction (200 c.c.) for the experimental work. The second was prepared by distilling 5,000 c.c. of the Utah crude No. 2 with steam but leaving a residue of 700 c.c. which was poured from the still while hot and is the "shale-oil residue" mentioned in the remaining portions of this paper.

The first sample, which for convenience will be designated as "cut ten," was a yellowish brown, sticky, semi-solid. It became much darker and slightly harder on exposure to air. When cooled slightly below room temperature the "shale-oil residue" was a black, lustrous solid, but very tenacious and sticky at higher temperatures. Tests were made on "cut ten" for specific gravity, saturation and solubility; and a portion was destructively distilled and the resulting oil examined. The results obtained with "cut ten" are given in Table IV. Solubility, saturation and fixed carbon determinations were made on the "shale-oil residue," using the methods for bitumens given in Richardson's "Modern Asphalt Pavement," 1910. A portion of this residue weighing 450 g. was destructively distilled at atmospheric pressure from a 1,000-c.c. Pyrex distilling flask. The yields of gas, coke and oil were measured and the oil fractionated into 10 per cent fractions, each of which was tested for gravity and saturation. The "shale-oil residue" and the oil obtained from it by distillation were analyzed for sulphur by the method of Waters[1] and for nitrogen by the Kjeldahl modification already described. The data obtained with the "shale-oil residue" and the oil produced from it by distillation are given in Table V.

Discussion of the Results in Tables IV and V

"Cut ten" and the "shale-oil residue" were found to contain 90 to 95 per cent of unsaturates and 83 to 88 per cent of malthenes; hence these heavy materials consist of a large proportion of unsaturated malthenes. The percentage of sulphur (0.37 per cent) in the "residue" is much lower and that of the nitrogen (2.05 per cent) higher than Richardson[2] gives for the malthenes of Trinidad asphalt (2.9 and 0.6 per cent respectively).

TABLE IV—DATA ON "CUT TEN" FROM STEAM DISTILLATION OF CRUDE SHALE OIL

Specific gravity	1.0216
Saturation, per cent	5.4
Solubility in carbon bisulphide, per cent	100.0
Malthenes, soluble in 84 deg., Bé. petroleum ether	88.0
Products of Distillation	
Water, per cent by weight (present as such in sample)	7.6
Oil, per cent by weight	65.0
Coke, per cent by weight	23.4
Gas, by difference	4.0

Changes Produced by Distillation	Gravity	Saturation Per Cent
Before distillation	1.0216	5.4
After distillation	0.959	50.0
Additional saturates	.....	27.8

Results of Fractionation	Per Cent	Saturation Per Cent
Water, by volume	0.28	....
Oil to 410 deg. F.	14.0	60.5
Oil to 572 deg. F.	21.1	49.5
Oil to 680 deg. F.	59.4	40.2
Gas and coke (by difference)	5.2	....

On distillation at atmospheric pressure "cut ten" and the "shale-oil residue" exhibit a greater decomposition, increase in saturation and loss of nitrogen than the crude shale oils. The "residue" formed 46.6 per cent of gas and coke, lost 72.8 per cent of the original nitrogen and formed 23.3 per cent of "additional saturates," while the Utah crude No. 2, from which this "residue" was obtained, yielded 16.7 per cent of gas and coke, 16.7 per cent of "additional saturates" and lost 28.2 per cent of the original nitrogen. These differences are, of course, caused by the higher content of the unstable materials in the "shale-oil residue." It is probable that the saturates of the "residue" do not decompose on distillation owing to greater stability, but the other materials evidently undergo almost complete decomposition, since 46.6 per cent is transformed into gas and coke, 23.3 per cent into "additional saturates" and 3.2 per cent is present as new unsaturates in the light highly

[1] *J. Ind. and Eng. Chem.*, vol. 12, p. 482.
[2] "Modern Asphalt Pavement," 1910, p. 170.

TABLE V—DATA ON "SHALE-OIL RESIDUE" FROM STEAM DISTILLATION

Specific gravity	1.015
Saturation, per cent	10.7*
Solubility in carbon bisulphide, per cent	99.8†
Malthenes, soluble in 84 deg. Bé. petroleum ether, per cent	83.6†
Carbenes, soluble in CS_2 but insoluble in CCl_4, per cent	0.26
Fixed carbon, per cent	10.6
Sulphur, per cent	0.37†
Nitrogen, per cent	2.05†

Products of Distillation

Water, per cent by weight	0.2
Oil, per cent by weight	53.2
Coke, per cent by weight	36.2
Gas, by difference	10.4

Changes Produced by Distillation

	Gravity	Saturation Per Cent	Nitrogen Per Cent	Sulphur Per Cent
Before distillation	1.015	10.7	2.05	0.37
After distillation	0.8578	54.0	1.05	0.34

	Per Cent.
Additional saturates	23.3
Loss of residue	46.8
Loss of nitrogen	72.8

Results of Fractionation

Percentage-off.	Temperature Deg. F.	Gravity (Of 10 per cent fractions)	Saturation (Of 10 per cent fractions)
10	307	0.718	72.0
20	345	0.777	67.0
30	427	0.817	63.0
40	477	0.844	60.0
50	525	0.865	56.8
60	567	0.875	54.0
70	605	0.894	52.0
80	645	0.904	48.8
90	705	0.913	47.0
98.25	700	0.929	38.1
Composite of above		0.854	56.0

Products of Distillation

Oil, per cent by weight	97.8
Coke, per cent by weight	1.3
Gas, by difference	0.9

* Determined by the method on p. 544, Richardson's "Modern Asphalt Pavement," 1910. This result is probably too high. This method is inaccurate for some bitumens the saturates from which are sticky, or hard and resinous, and certainly not paraffines but possibly neutral esters or polymers of unsaturates which are soluble in the petroleum ether and not removed by the treatment with acid and alkali. See Brooks and Humphrey, *J. Am. Chem. Soc.* vol. 40, pp. 847 and 856.

† The average of two determinations.

saturated fraction of the oil boiling below 346 deg. F. The oil obtained by the destructive distillation of the "residue" resembles the once-run Utah oil No. 2 in that it does not decompose on distillation and in the distribution of the saturates, but the boiling point and specific gravity of the fractions are lower and the saturation higher than in the fractions of the once-run oil. Since the once-run oil from the Utah crude No. 2 contains less than 46 per cent of saturates, while that from the "residue" obtained from this crude contains 54 per cent of saturates, and since the secondary gasolines have a higher saturation than the primary gasolines, it is probable that the materials escaping decomposition in the retort crack on distillation with a higher yield of saturates than the materials that decompose in the retort. The most remarkable property of the decomposition of the "shale-oil residue" is the large yield of saturates, the greater portion of which consists of lighter oils (72 per cent of the first 10 per cent fraction).

Crude shale oils are apparently composed of comparatively light stable oils of higher saturation produced by decomposition during retorting and of heavy unstable materials of lower saturation that have escaped decomposition in retorting because of rapid removal as vapor and fog by the gases and lighter oils. The decomposition from kerogen to once-run oil tends to occur in two stages—a primary decomposition in which the insoluble kerogen is changed, possibly by depolymerization, into soluble heavy unstable materials similar to the "shale-oil residue"; and a secondary decomposition (not depolymerization) in which these unstable materials are broken down into lighter oils of greater stability and higher saturation such as constitute the once-run oils. Since the secondary gasolines and the light fractions of the oil from the "shale-oil residue" have a higher saturation than the primary gasolines, the primary decomposition must also yield light oils which contain a larger proportion of unsaturates than the light oils formed by the secondary decomposition; or the primary decomposition produces unstable materials lighter than the "shale-oil residue" which yield on secondary decomposition a larger percentage of unsaturates than the heavy "residue" examined in this work. Retorting with steam and inert gases tends to prevent the secondary decomposition[5] by carrying over larger amounts of the bitumen produced by the primary decomposition, and as a result the crude oil contains a higher percentage of the unstable unsaturated materials. Destructive distillation of shale or distillation of crude shale oil at slower rates or under any conditions which tend to prevent the removal of the primary products in the form of fog (heavy non-gaseous vapor) causes a more complete secondary decomposition and produces an oil of the once-run type. Much of the so-called high-temperature retorting apparently evolves the products so rapidly that the gases and lighter oils carry large proportions of the primary products out of the hot zone before the slower secondary decomposition has progressed far, and the crude oil is consequently more highly unsaturated. It is evident that physical conditions during retorting can be so controlled as to obtain a maximum of the bituminous products of the primary decomposition or an oil similar in quality to the once-run oils in which the secondary decomposition is complete, and that consideration of these two stages of the decomposition is important in the construction and operation of retorts on a commercial scale. Since the heavy primary decomposition products of shale may prove to be of commercial importance, these materials should be thoroughly investigated.

Summary

1. Crude oils from shales of wide geographical distribution and of varied chemical composition have been examined and their heavy fractions found to decompose on distillation at atmospheric pressure. The decomposition is accompanied by the formation of coke, gas and lighter oils which contain considerably more saturates and less nitrogen than the original crude oil. The increase in saturates appears to be associated with the loss of nitrogen rather than with the loss of oil.

2. The light oils obtained by the decomposition of crude shale oil are a little higher in saturation than the light oils present in the crudes before the decomposition but in other respects these light oils are similar.

3. The undecomposed bitumen from a crude shale oil was found to consist largely of unsaturated malthenes, high in nitrogen and low in sulphur. A sample of this material decomposed almost completely on distillation at atmospheric pressure forming coke, gas and lighter stable oils which contained a larger proportion of saturates, but a similar percentage of nitrogen to that in the once-run oil from the same crude as this bitumen. This unstable material is a primary decomposition product of kerogen and is the parent material from which the lighter, more saturated stable oils are formed by a further secondary decomposition. Crude shale oils as usually obtained consist of both primary and secondary decomposition products.

The author wishes to express his indebtedness to R. W. Boyd, who did the experimental work with the shale oils from California, Kentucky and England.

[5] CHEM. & MET. ENG., vol. 24, May 18, 1921, p. 877.

Grain Growth and Recrystallization in Metals II—Experimental Data and General Laws

Consideration of the Effect of Time and Temperature of Heating, Degree of Cold-Work, Original Grain Size and Obstructing Impurities on the Grain Growth of Metals and Solid Solution Alloys —Non-Uniform Conditions Have Powerful Effect on Results of Any Treatment*

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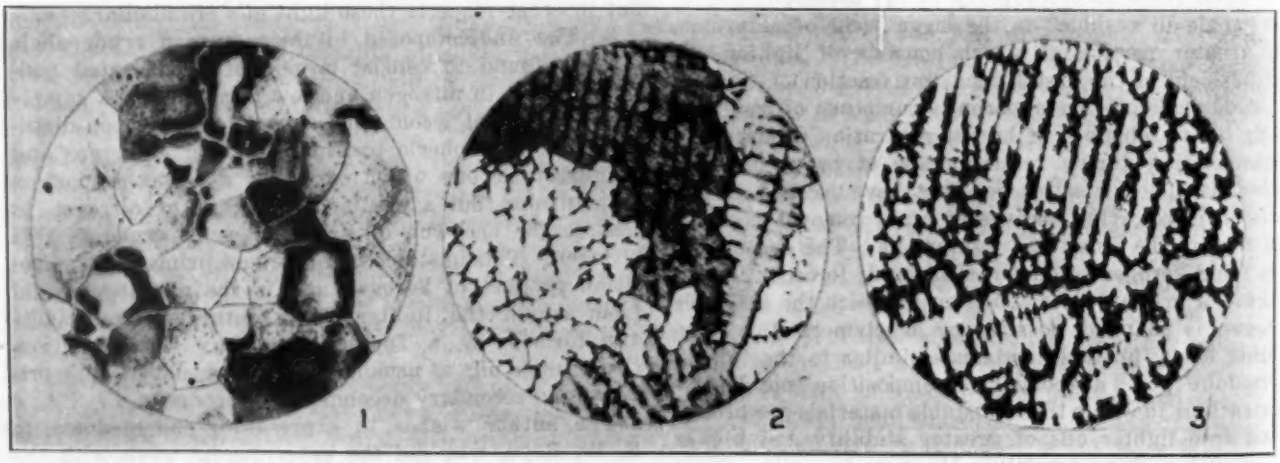
THE appearance of the grains of a cast metal on a plane surface cut through the metal usually gives no indication of the mechanism of their formation. Each grain appears uniform within its own boundaries and does not suggest that it has grown by a process of dendrite formation. That such is the case is revealed by examining an exterior surface of the metal which has been allowed to solidify freely and upon which the dendrites will usually be found in relief. An illustration was given in an article by the present authors entitled "The Crystalline Structure of Metals" (CHEM. & MET. ENG., May 4, 1921, p. 771). Fig. 1 is a micrograph of a cast brass containing 90 per cent copper and 10 per cent zinc. The structure approximates that of a pure metal, showing pohydedral grains uniform in appearance within themselves except for slight changes in etching tint due to concentration of the zinc near the grain boundaries. This effect is known as "coring" and regularly occurs during the solidification of alloys which in equilibrium consist of homogeneous solid solutions.

CORED CRYSTALS

As the amount of impurity increases the coring effect becomes more marked. In Fig. 2 is shown a cast brass containing 70 per cent copper and 30 per cent zinc. Under equilibrium conditions about 35 per cent of zinc is soluble in copper in the solid state, but equilibrium is not attained during solidification and the structure shows marked coring with perhaps the separation of a second phase. The dendritic structure of the primary copper-rich grains is clearly shown. Fig. 3 shows a similar structure in cast Monel metal, which contains about 60 per cent nickel, 35 per cent copper and 5 per cent iron and manganese. Both this alloy and the 70:30 brass after working and annealing exhibit perfect solid solution structures, indistinguishable under the microscope from those of a pure metal. These illustrations show not only the tendency of metals to crystallize in the form of dendrites but also that the solid solution alloys are not homogeneous solid solutions in the cast state. This is important because the discussions below deal with grain growth in substantially pure metals and solid solution alloys which after a homogeneous structure is produced follow the same laws of grain growth as pure metals.

On solidification the amount of the added element in an alloy of the solid solution type influences the grain size. This is particularly true in case of sharp variations of temperature between different parts of the solidifying alloy. Whereas pure metals cast in iron molds or otherwise caused to solidify rapidly nearly always show smaller grains than when cast in sand molds or caused in any other way to solidify slowly, solid solution type alloys often show larger grains when cast in chill molds. There seems to be a certain temperature gradient and composition favoring the formation of large grains. The solidification of an ordinary steel ingot in an iron ingot mold seems to produce the proper conditions for large grains in the exterior of the ingot and considerably smaller grains in the interior. It should be remembered that the grain size of cast

*Part I, on Definitions, was published in CHEM. & MET. ENG., vol. 26, No. 8, Feb. 22, 1922, p. 343.



FIGS. 1 TO 3

Fig. 1—Cast 90:10 Brass (Bassett). Fig. 2—Cast 70:30 Brass (Bassett). Fig. 3—Cast Monel Metal (Merica).

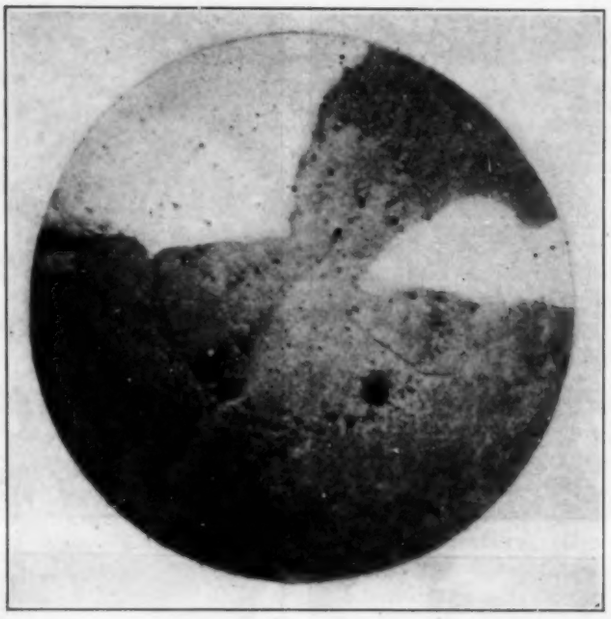


FIG. 4—COARSE-GRAINED TUNGSTEN BRIQUET FUSED AT CENTER. × 25

metals is always large as compared with that ordinarily found in worked metals.

The effect of existing crystals on the crystallization of a liquid is well known. If a crystal of a salt is put in a saturated water solution of the salt and the temperature lowered, the existing crystal grows larger. The added material assumes the same orientation as the original crystal. If the temperature is lowered very gradually, no new crystals may form. This is only one of many cases illustrating that when a liquid solidifies, existing crystals form "nuclei" on which the liquid crystallizes. A good example of this rule was observed when a coarse-grained tungsten ingot was heated by the passage of electric current until the central or axial portion fused. Fig. 4 shows that the grains in the resolidified portion are continuations of the grains in the unfused portions.

When a fine-grained tungsten ingot was fused in the center, however, the metal resolidified in such manner that each grain in the resolidified portion was adjacent to about 100 of the original grains. The structure of such an ingot is shown in Fig. 5. (Sykes). This relatively coarse-grained structure is produced in spite of a rapidity of solidification perhaps seldom equaled in any other metal. The fusion of the ingot breaks the electrical contact and in about one minute the ingot cools from 3,400 deg. C. to about 50 deg. C. Such a cast structure does not show grain growth in the solid state even with long exposures at temperatures slightly below the melting point.

Normal Grain Growth in Solid Metals

Grain growth in the solid state in worked metals and solid solution alloys can be illustrated by the behavior of alpha brass. The structure of a 70:30 brass as cast is shown in Fig. 2. After hot-working or cold-working and heating to a temperature around 600 deg. C. the structure is that of a homogeneous solid solution composed of equiaxed grains. In worked brass the grains are nearly always twinned, although twins are not found in the casting. The history of change in grain size with change in temperature in a 68:32 brass after 50.9 per cent reduction in thickness by cold-rolling is shown in Figs. 6 to 13 inclusive (Bassett and Davis). No grain growth takes place until a temperature of about 275 deg. C. is reached and the cold-worked structure is completely replaced by small equiaxed grains at 400 deg. C. after 30 minutes' exposure. As the temperature increases the grain size increases.

The increase in grain size with temperature can be seen qualitatively in the micrographs and is plotted in Fig. 14. The shape of this curve is similar to that found for many metals by various observers, including Mathewson and Phillips[1] working on alpha brass; Mathewson[2] on copper-tin alloys with 2.4 and 8 per cent tin, and Mathewson and Thalheimer[3] for copper. Rapid increase in grain size begins at about 700 deg. C. for copper.

Although this type of curve is normal for many metals, there are many factors which may and often do cause marked deviations. McAdam[4] shows that cold-worked Armco iron annealed for either 7- or 14-hour periods has a fairly constant grain size up to about 800 deg. C., above which temperature there is a marked grain growth. His temperature-grain size curves are more flat at low temperature than the one shown in Fig. 14, but the increase in grain size above 800 deg. C. is more pronounced than in alpha brass above 600 deg. C. One of the authors has found that the normal grain size-temperature curve for briquetted and sintered tungsten powder[5] is more nearly a straight line than that of Fig. 14. Sometimes when abnormal growth occurs the curve may depart from the normal type entirely within certain temperature ranges.

The time of exposure at the various temperatures is an important factor in the resulting grain size, especially at the lower temperatures. In alpha brass a grain size is reached after a comparatively short time, say 30 minutes, at 650 deg. C., which does not change to any marked extent with longer exposures. If the temperature is 325 deg. C., the time necessary to establish apparent equilibrium grain size is measured in days. Fig. 15 shows the time necessary at various temperatures to produce a given amount of softening in alpha brass (Mathewson and Phillips). If, however, the temperature is raised to a little below the melting point, a fraction of a minute is often sufficient to produce a grain size which does not change noticeably on further exposure. Incandescent lamp filaments of tungsten operated

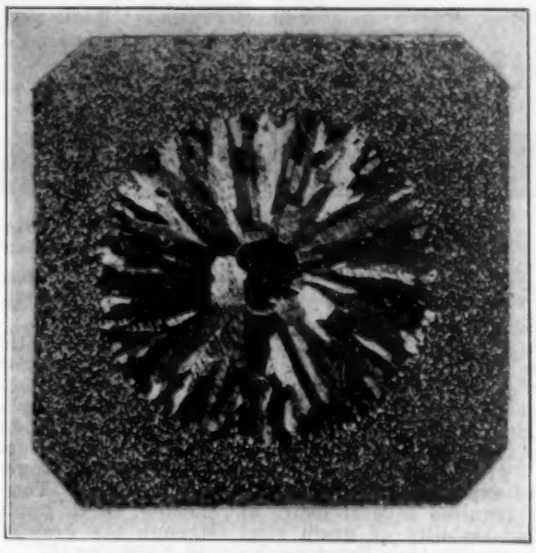


FIG. 5—FINE-GRAINED TUNGSTEN BRIQUET FUSED AT CENTER. × 6. (SYKES)

at a temperature of about 2,100 deg. C. usually exhibit growth until "burn out," which is sometimes as long as 90 days' total heating[5]. The same filaments can be heated to a temperature just below the melting point (3,400 deg. C.) and in a few minutes or sometimes in a fraction of a minute a

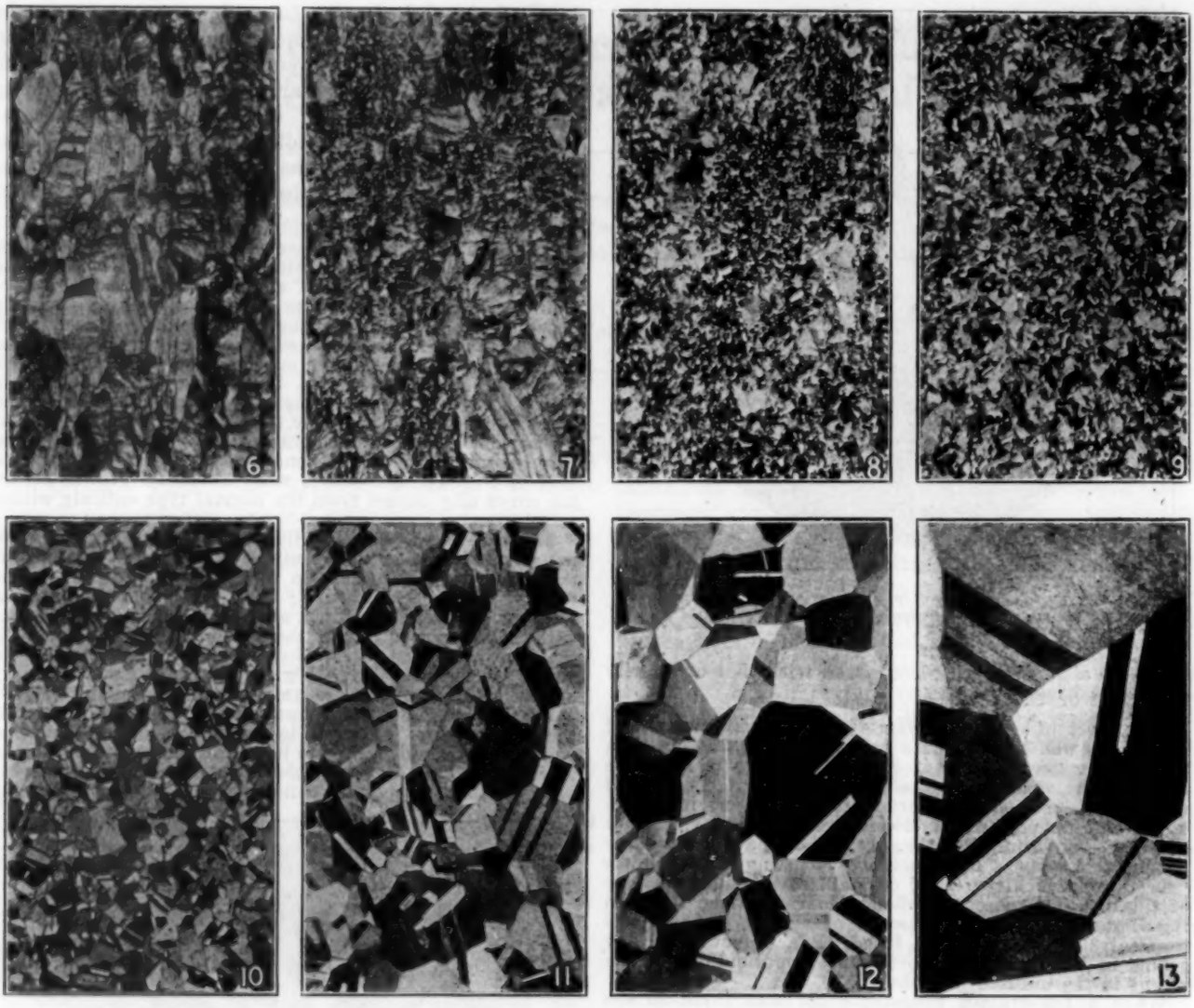
[1] "Recrystallization of Cold-Worked Alpha Brass on Annealing," Mathewson and Phillips, *Trans.*, A.I.M.E., vol. 54 (1916), pp. 608-670.

[2] "Metallographic Description of Bronzes From Machu Picchu, Peru," Mathewson, *Am. J. Sci.*, vol. 40, December, 1915, p. 546.

[3] "Comparisons Between Electrolytic Copper and Two Varieties of Arsenical Lake Copper With Respect to Strength and Ductility in Cold-Worked and Annealed Test Strips," Mathewson and Thalheimer, *Am. Inst. Min. Eng.*, vol. 55 (1916), pp. 446-485.

[4] "Grain Size of Iron as Affected by Temperature," McAdam, A.S.T.M., vol. 18 (1918), Part II Technical Papers, pp. 68-86.

[5] "The Metallography of Tungsten," Jeffries, A.I.M.E. (1919) vol. 60, pp. 588-656.



FIGS. 6 TO 13—EFFECT OF 30-MINUTE ANNEAL ON GRAIN SIZE OF 68:32 BRASS, REDUCED COLD 50.9 PER CENT. × 75 (BASSETT AND DAVIS)

Fig. 6—As rolled. Fig. 7—Annealed at 300 deg. C. Fig. 8—Annealed at 350 deg. C. Fig. 9—Annealed at 450 deg. C. Fig. 10—Annealed at 550 deg. C. Fig. 11—Annealed at 650 deg. C. Fig. 12—Annealed at 750 deg. C. Fig. 13—Annealed at 850 deg. C.

grain size will be produced which does not change noticeably when the filament is subjected to a lower temperature; at 3,000 deg. C. 30 seconds often suffice.

A severely cold-drawn nickel:iron alloy containing 56 per cent iron and 44 per cent nickel with a melting point of about 1,475 deg. C. was heated to 1,200 deg. C. for 30 seconds and a grain size was developed which did not change with longer exposure at that or lower temperatures. The same alloy required several hours at 725 deg. C. to produce a similar stability of grain size, although the grains were much smaller than those produced at 1,200 deg. C.

Armco iron containing only 0.02 per cent carbon was pressed cold and heated to 850 deg. C. At the end of 1 hour the average grain diameter was 0.0022 in. At the end of 10 hours this had increased to 0.0077 in. and after 168 hours the average grain diameter was 0.25 in. How much longer this growth would have gone on is not known, as the test was not continued.

The important conclusions from these observations are (1) that under some conditions of temperature, particularly at relatively high temperatures, a grain size is established in a very short time which is stable so long as the metal is not subjected to a higher temperature, and (2) that there is in some metals an intermediate temperature range (which is around 2,100 deg. C. for tungsten and 850 deg. C. for iron) at which grain growth continues for long periods and very large grains may be developed. This intermediate temperature range is not found in all metals. When it does obtain, an abnormal grain size may develop. Carpenter and Elam[6] report that large grains are developed in commercial aluminum sheet severely worked and annealed for 2 weeks at 550 deg. C.

RECRYSTALLIZATION

A great amount of work has been directed toward the study of the phenomena of recrystallization. Recrystallization has been defined in the first of this series of articles as the change from the strain-hardened to the un-strain-hardened condition. When recrystallization is complete the small unstrained grains grow into larger unstrained grains in accordance with the general rules just considered.

The greater the degree of strain-hardening the lower will be the temperature of recrystallization. Consequently with a metal of a given composition—i.e., a given degree of purity—anything which will increase the degree of strain-hardening will decrease the recrystallization temperature. The amount of deformation effected below the recrystallization temperature is one

[6] "Crystal Growth and Recrystallization in Metals," Carpenter and Elam, *J. Inst. Metals*, No. II (1920).

factor influencing the degree of strain-hardening. The general rule is that the recrystallization temperature is lower the greater the amount of cold-work.

Mathewson and Phillips show that in alpha brass, previously annealed at 800 deg. C., recrystallization after 4 per cent reduction in area by cold-rolling requires a temperature of 650 deg. C., and after 40 per cent reduction the temperature is 350 deg. C. for a 30-minute anneal. Carpenter and Elam[4] show that commercial aluminum sheet previously annealed for 6 hours at 550 deg. C. and then elongated 2 per cent at room temperature did not show recrystallization or at least complete recrystallization after 65 hours' heating at 500 deg. C. With 4 per cent or more elongation recrystallization was complete under these conditions of time and temperature. With severe cold work the recrystallization temperature may be lowered to 200 deg. C. or less. Usually in such cases the grain size is smaller the greater the previous deformation.

Grain size prior to cold deformation is an important factor in connection with the degree of strain-hardening and hence greatly affects the recrystallization temperature. The smaller the grains the greater is the strain-hardening effect of a given amount of deformation and the lower is the recrystallization temperature. Fine-grained metal elongated 1 per cent may have a lower recrystallization temperature than a coarse-grained metal elongated 5 per cent or more. This disparity in grain size prior to cold deformation may even produce such marked difference that a coarse-grained metal elongated as much as 5 per cent will not recrystallize at a temperature which will cause normal grain growth in an annealed but fine-grained sample of the same metal. For example, a severely cold-worked aluminum sheet heated for several hours at 250 deg. C. will recrystallize. The grains will be small. If the same piece is heated to 300 deg. C., grain growth will take

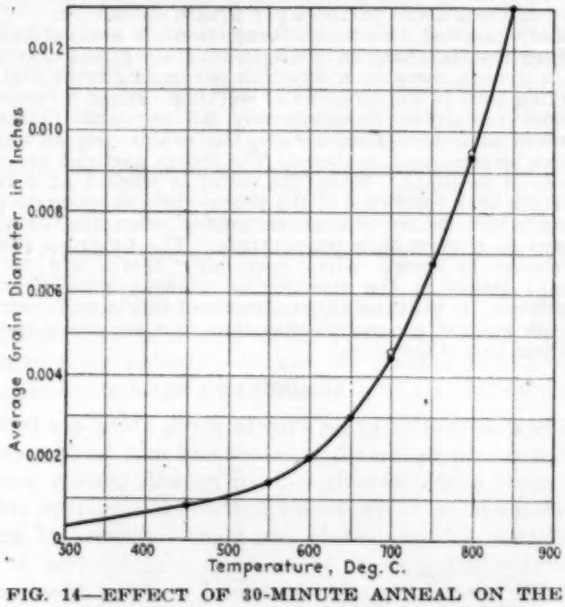


FIG. 14—EFFECT OF 30-MINUTE ANNEAL ON THE GRAIN SIZE OF 68:32 BRASS COLD-ROLLED 50.9 PER CENT. (BASSETT AND DAVIS)

place. A very coarse-grained sample stretched 5 per cent cold may show no signs of recrystallization at 300 deg. C.

Time of exposure at temperature is an important factor in the temperature of recrystallization (refer to Fig. 15). A cold-worked metal which might show only partial or no visible signs of recrystallization in 5 minutes might show complete recrystallization in an hour or more. So far as tests go it seems that the recrystallization temperature becomes lower the longer the time of exposure. When the temperature which will cause recrystallization with a few hours exposure is found, a slight decrease in temperature causes an enormous increase in time to produce recrystallization. So great is this effect that a temperature is found not far below the ordinary recrystallization temperatures which would necessitate an exposure of years to produce recrystallization.

The temperature of deformation is also a factor in determining the recrystallization temperature. The lower the temperature at which the deformation is effected the lower will be the recrystallization temperature. A possible exception to this general rule is iron worked at a temperature near 200 deg. C.

The purity of a metal is also an important factor in connection with the recrystallization temperature. As a rule a solid solution alloy has a higher recrystallization temperature than the solvent metal. For example,

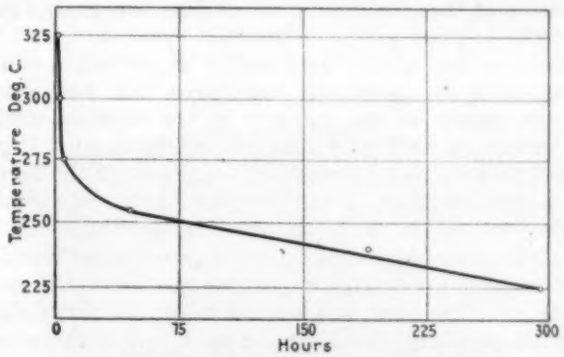


FIG. 15—CARTRIDGE BRASS (70:30) COLD-ROLLED 40 PER CENT. TIME NECESSARY TO DROP 3 POINTS IN SCLEROSCOPE HARDNESS. (MATHEWSON AND PHILLIPS)

severely strain-hardened alpha brass containing 34 per cent zinc has a recrystallization temperature of about 300 deg. C., whereas severely strain-hardened copper has a recrystallization temperature of about 200 deg. C. Impurities producing mechanical obstruction to grain growth also increase the recrystallization temperature.

The recrystallization temperature not only varies for different treatments of different pieces of the same metal, but it varies within the same piece of metal if a homogeneous condition does not exist. Since with mild cold deformation and large grains it is impossible to produce a condition even approximating homogeneity, such samples usually recrystallize over a considerable *range* of temperature. The greater the amount of strain-hardening the smaller this range will be—that is, the complete change in structure from strained to unstrained grains will take place within a small temperature range. Since the properties depend on the structure, there is a marked change with a small temperature change.

If we consider the temperature at which recrystallization is just complete, it is observed that the lower the recrystallization temperature the smaller the grain size. When some condition is varied which raises the temperature of complete recrystallization, such as the amount of deformation, the grain size after complete recrystallization is larger than with the lower recrystallization temperature. With a given recrystallization temperature there is a certain *minimum* grain size which can be produced. This minimum is less the lower the recrystallization temperature in any particular metal.

The disparity in grain size produced by varying the recrystallization temperature tends to disappear as nor-

mal grain growth proceeds above the recrystallization temperature. Equality of grain size is produced only at high temperatures. Figs. 16 to 21, of alpha brass cold-worked different amounts and then heated for 30 minutes at 550 deg. C., show how the grain size becomes smaller as the recrystallization temperature decreases. The grain sizes of the more severely deformed samples were still smaller at temperatures only slightly above recrystallization. If all were heated to about 800 deg. C., the grain sizes would be approximately equal.

The history of recrystallization can be studied by subjecting strain-hardened metal to various temperatures and cooling and examining with a microscope after recrystallization has commenced but before it is completed. This has been done by Chappell[1] on iron, Mathewson and Phillips[2] on alpha brass and Carpenter and Elam[3] on aluminum. In all cases recrystallization begins at the old grain boundaries, preferably at the junction of three original grains. The new grains grow into the original grains with about equal ease.

Because new grains first appear at old grain boundaries, it is too commonly considered that new grains do not appear in the interior of the original grains. By referring to Fig. 9 and comparing it with Fig. 6 it will be obvious that many of the grains in the former must have formed in the interior of the old grains. A case which has been observed frequently is the recrystallization of coarse-grained tungsten after working. The original grains in a particular case were 0.25 in. in diameter. The ingot was worked below its recrystallization temperature about 50 per cent reduction in area and then heated quickly to a temperature well above that of lowest recrystallization. The grains then measured 0.008 in. in diameter. *Most* of the new grains were formed inside the original grains.

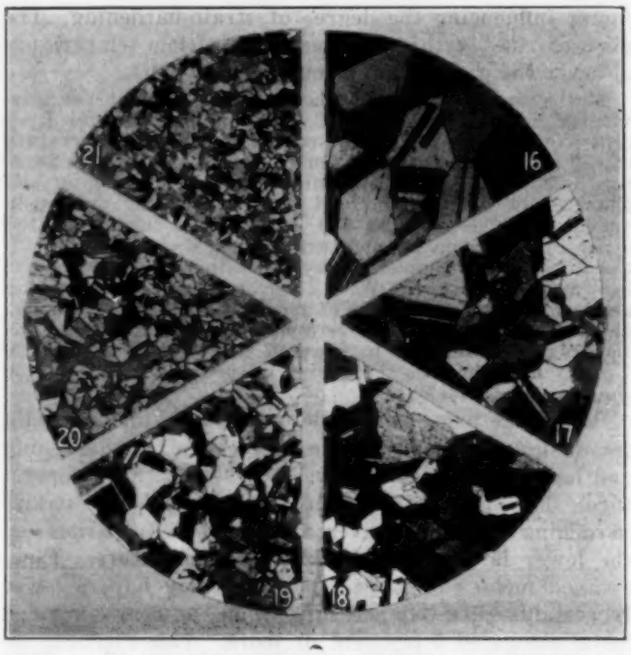
Compressed Powders

Grain growth in the solid state in compressed metal powders has been studied most extensively with tungsten[4]. The metal does not consolidate until a temperature is reached far above that of recrystallization after severe cold-work. In tungsten the density of the compressed briquet is usually about 60 per cent that of the consolidated metal. The temperature at which the density becomes normal is about 2,400 to 2,600 deg. C., which is at least 1,000 deg. C. above the temperature of lowest recrystallization after severe cold-working. After the briquet has consolidated it consists of very small grains, which, however, are larger than the original particles of powdered metal. Higher temperatures normally produce larger grains, the same as in recrystallized metals. Special cases of abnormal grain growth in compressed tungsten briquets will be considered in connection with "germination."

Obstruction

Any foreign matter in a metal affects the grain growth characteristics. The foreign matter may be in solution in the metal, it may be present as a mechanical inclusion or as a separate phase or constituent of an alloy. A good example of mechanical obstruction to grain growth is thoria (ThO_2) intentionally added to tungsten for the purpose of retarding the rate of grain growth or of producing smaller grains at any given stage in the life of a lamp. The effect of such obstruction is to introduce resistance to grain growth in approximate proportion to the amount of surface of the obstruction particles. A given amount of obstruction material therefore offers more resistance to grain growth the smaller the particles, or with given sized particles the greater the amount of obstructing material the greater will be the resistance to grain growth.

[1]Chappell, *J. Iron and Steel Inst.* (1914), No. 1, pp. 460-496.



FIGS. 16 TO 21—ALPHA BRASS HEATED 30 MINUTES AT 550 DEG. C., AFTER VARIOUS AMOUNTS OF COLD-WORK. × 60. (MATHEWSON AND PHILLIPS)

Fig. 16—Reduced 4 per cent. Fig. 19—Reduced 15 per cent.
Fig. 17—Reduced 8 per cent. Fig. 20—Reduced 23 per cent.
Fig. 18—Reduced 12 per cent. Fig. 21—Reduced 50 per cent.

Thoria is introduced as thorium nitrate into the tungstic oxide before the latter is reduced by hydrogen to tungsten powder. The heating changes the thorium nitrate to oxide. Thoria is present in such small particles that they are not visible except under a high-powered microscope. With 0.75 per cent thoria present a polished section may cut about 5,000 of these small particles per square millimeter.

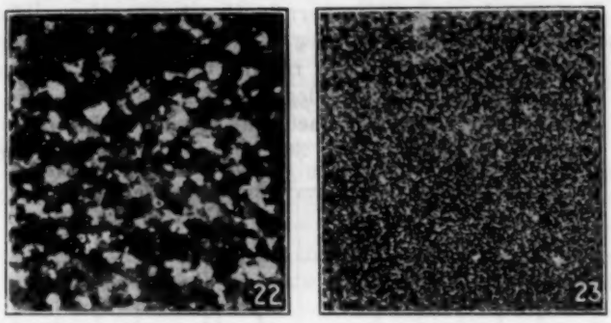
Many cases of directional obstruction are encountered in worked metals. Slag in wrought iron sometimes obstructs grain growth more in a direction perpendicular to that of working than in the direction of working. When a tungsten briquet containing approximately 0.5 per cent thoria is sintered at a high temperature, the grains are, as nearly as can be measured, equiaxed. The thoria particles are also equiaxial in shape. When the metal is worked at a temperature near 1,300 deg. C. the thoria globules elongate into fibers which do not change materially when the metal is heated to a very high temperature. The tungsten grains developed in drawn wires containing thoria are nearly always longer in the direction of working than in other directions. It is obvious that threads of thoria will obstruct growth more in a perpendicular than in a parallel direction to their long dimensions[5].

Gradients

The examples of grain growth given above are typical of the results ordinarily obtained and may be considered "normal" grain growths. Such growth usually results when the metal is reasonably uniform in structure and is uniformly heated. There are many instances of grain growth which seem to be in direct contradiction to the laws of normal growth. A careful study of these cases usually reveals that some non-uniformity either in structure or in temperature has been responsible for the apparent paradox.

The most important type of structural non-uniformity is that due to variable strain and may be referred to as a *strain gradient*. There are two types of strain gradient to be considered—"general" and "local." A

[5]Although the thoria fibers are so small that they cannot be seen even with a high-powered microscope, their presence in fibrous form is indicated by the behavior of a coiled wire, when the tungsten is removed by HCl at a dull red heat. The thoria remains in the form of the original coils. When unworked wire is treated with hot HCl gas, the thoria remains unattacked chemically, but is found after the treatment in a compact mass on the bottom of the boat or other receptacle.



FIGS. 22 AND 23—STEEL (0.05 C) HEATED 7 HOURS AT 650 DEG. C. AFTER LOADING. × 6. (SAUVEUR)

Fig. 22—Stressed cold to 40,000 lb. per sq.in.
Fig. 23—Stressed cold to 38,000 lb. per sq.in.

general strain gradient consists in a gradual variation in the degree of strain over a considerable distance in the metal, such as is produced when a bar is bent or when a Brinell impression is made. A general strain gradient is the result of a grossly non-uniform mechanical deformation, but no deformation, however uniform, can be effected without introducing local variations in strain from grain to grain or in different parts of the same grain. These are referred to as local strain gradients.

A second type of structural non-uniformity consists in a non-uniform distribution of material which mechanically obstructs grain growth, and may be designated an "obstruction gradient." Obstruction gradients are generally local in character.

Variations in temperature within a piece of metal are referred to as *temperature gradients*. Temperature gradients always exist during heating or cooling, and are greater the faster the change in temperature. The outside of a piece of metal is always hotter during heating than the inside, unless the heat is generated within the metal, as by the passage of an electric current, in which case the inside may be very much hotter. In ordinary muffle heating the rate is so slow that only small temperature gradients exist, and if the temperature distribution in the furnace is good, the metal may be considered substantially free from temperature gradients. When temperature gradients exist they often play an important rôle in grain growth.

Certain combinations of non-uniformity of structure or temperature give rise to what may be termed "exaggerated grain growth"—that is, the production of grains of abnormally large size. Any case of the development of abnormally large grains may be called *germination*.[9] The temperature range within which the abnormally large grains are formed is called the germinative temperature.

Some typical examples of germination will be considered.

An important type of exaggerated growth was reported by Prof. A. Sauveur,[10] in soft steel containing about 0.05 per cent carbon, given a preliminary normalizing treatment by heating to about 900 deg. C. and cooling in air. Test-pieces were then subjected to definite degrees of strain by stretching in a tensile machine. Prof. Sauveur expressed the strain in terms of the stress to which the specimens were loaded. This is not, of course, an accurate measure of strain if materials of different stress-strain characteristics are being used, but where all experiments are carried out on the same material the stress does indicate the strain. A specimen stretched by a unit load of 40,000 lb. per sq.in. and then annealed for 7 hours at 650 deg. C. showed a marked increase in grain size (Fig. 22). A similar specimen loaded to 38,000 lb. per sq.in. and annealed in the same manner showed no grain growth, nor did germination result if the specimens were loaded to 42,000 lb. per sq.in. or more (Fig. 23).

Similar results are shown qualitatively by making a Brinell impression in a piece of mild steel and then heating it 7 hours at 650 deg. C. The strain is, of course, greatest immediately below the impression and decreases gradually as the distance from the impression increases. In a certain zone marked by coarse grains the strain is just right to produce germination.

Prof. Sauveur bent another bar of mild steel cold and gave it the same heat-treatment. Fig. 24 shows how germination took place in a certain zone between the axis and outside of the bar. Another very clear illustration of the facts is seen

FIG. 24—STEEL (0.05 C) BENT COLD AND HEATED 7 HOURS AT 650 DEG. C. × 6. (SAUVEUR)

in Chappell's[7] tapered bar shown in Fig. 25. The strain increases continuously toward the small end of the bar. It will be noted that, as the degree of strain increases, the point at which grain growth begins is sharply marked. With still further strain, however, the grain size decreases in a gradual rather than abrupt manner.

Prof. Sauveur concluded that there is a critical strain which produces germination. He was unable to produce marked grain growth in Armco iron containing only about 0.02 per cent carbon or in steels containing over about 0.12 per cent carbon. He reports, "It would seem therefore that we must also recognize the existence of a critical carbon content (0.04 to 0.12 per cent) above or below which ferrite grains will not grow on annealing below the range, even if they have been critically strained." The effect of carbon is undoubtedly one of mechanical obstruction to grain growth, so that, translating this last conclusion, we may say that there is a critical amount of obstruction for exaggerated grain

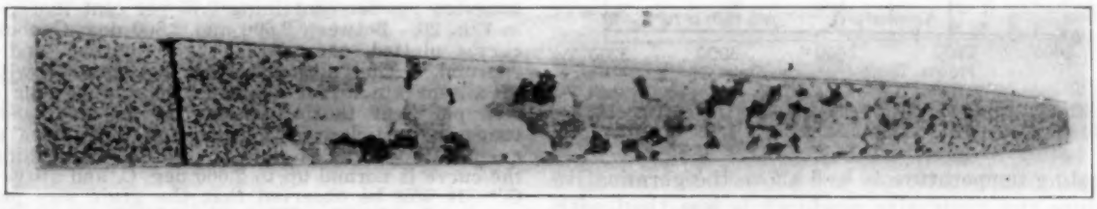


FIG. 25—STRAIN GRADIENT PRODUCED BY STRESSING TAPERED BAR, SUBSEQUENTLY HEATING TO 870 DEG. C. × 5. (CHAPPELL)

[9] "On Grain Growth," H. M. Howe, *Trans.*, A.I.M.E., vol. 56, p. 582.

[10] "The Metallography and Heat-Treatment of Iron and Steel," A. Sauveur, pp. 265-271.

growth. It is now known that some coarsening will occur in steels containing less than 0.04 and more than 0.12 per cent carbon, but the maximum effect is obtained in the range named by Sauveur. It is also now recognized that "critical strain" applies to only one set of conditions as to annealing temperature and obstruction. For each degree of strain there is a critical temperature for germination.

This law is well illustrated by Ruder's results on silicon steel[11] (essentially a solid solution alloy). Pieces of silicon steel sheet were annealed at 1,100 deg. C. and then subjected to various amounts of cold deformation by stretching. Pieces with each degree of strain were heated for 10 hours at 750, 800, 950 and 1,100 deg. C. The results are expressed qualitatively in Table I, where the amount of strain is expressed as per cent elongation. Only three degrees of grain growth are indicated. A blank space indicates that no growth has occurred. "Coarse" indicates very large grains, and "medium" indicates that some growth has occurred, but that the grain size is not so great as where "coarse" is reported.

TABLE I.

Degree of Strain, Per Cent	Annealing Temperature, 750 ° C	800 ° C	950 ° C	1100 ° C.
0.625	.....	.....	.....	Coarse
1.25	.....	.....	Coarse	Medium
2.5	.....	Coarse	Medium	Medium
5.6	Coarse	Medium	Medium	Medium
6.75	Medium	Medium	Medium	Medium

Table I shows that the germinative temperature increases as the degree of strain decreases and that when

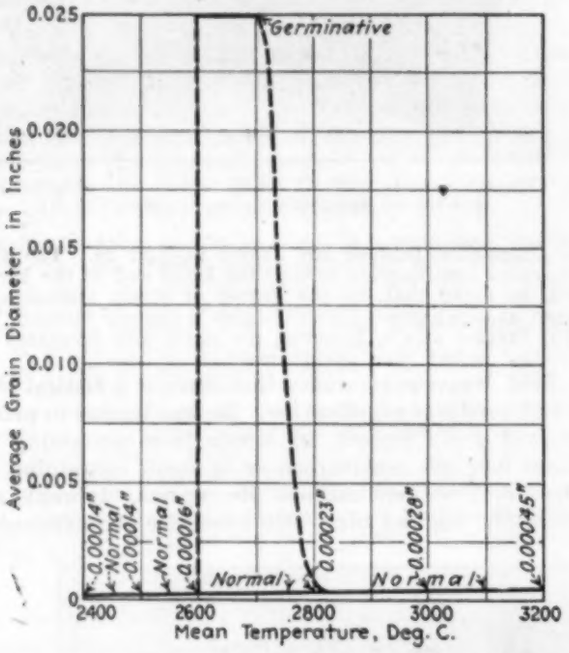


FIG. 26—GRAIN SIZE VS. TEMPERATURE FOR BRIQUETTED TUNGSTEN CONTAINING 0.75 PER CENT THORIA

the annealing temperature is well above the germinative temperature the grain size produced is less than with the same degree of strain but an anneal at the germinative temperature. An additional fact not brought out in the table is that as a rule the grain size produced at the germinative temperature is larger the higher the germinative temperature—that is, the less the strain.

This series shows the effect of rate of heating through the germinative temperature on grain size. For example, in the 800 deg. C. series the 2.5 per cent elongation sample was at its germinative temperature. Consequently in the 1,100 deg. C. series the 2.5 per cent sample was heated rather rapidly through the temperature range around 800 deg. C. and the grain size is smaller in spite of the fact that it was maintained 10 hours at a temperature 300 deg. C. higher. If the

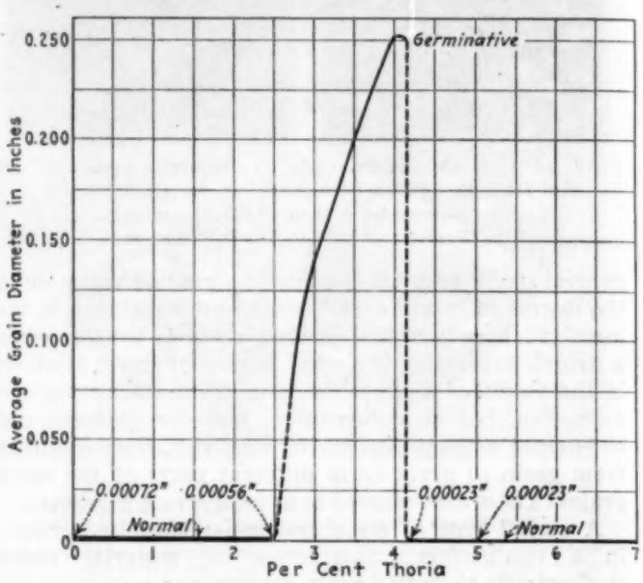


FIG. 27—EFFECT OF THORIA ON GRAIN SIZE OF TUNGSTEN

heating had been slow or if the steel had been maintained at the germinative temperature a long time during heating to 1,100 deg. C., the grain size could not have been smaller than in the 800 deg. C. series and might have been larger.

An example of exaggerated grain growth in tungsten was reported by one of the authors.[12] The normal grain growth-temperature curve for these tungsten briquets in shown by the straight line in Fig. 26. Exaggerated growth can be produced by using metal with a certain obstruction to growth and varying the temperature, at the same time maintaining a temperature gradient. Fine-grained tungsten powder containing 0.75 per cent ThO_2 was briquetted and heated to 2,600 deg. C. by the passage of electric current and held 30 minutes. The portion of the rod near the surface was very fine grained, that at the axis somewhat coarser and the intervening portion was very coarse grained. The axis of the rod was the hottest and the surface the coolest. A briquet of this metal heated quickly to 3,200 deg. C. develops a fairly uniform grain size throughout the briquet and only about one one-thousandth the size of that produced at 2,600 deg. C.

The results of a set of tests on briquets made of very fine tungsten powder containing 0.75 per cent thoria are shown in Fig. 26. Between 2,600 and 2,800 deg. C. there are two curves plotted, one marked "germinative" and the other "normal." The "normal" curve was obtained with briquets of a separate lot of coarser tungsten powder containing 0.75 per cent thoria. Owing to the coarseness of the tungsten particles, no germination took place and consequently the curve is normal. In the fine-grained powder the curve is normal up to 2,600 deg. C. and above 2,800 deg. C.[13] It will be observed that the grain size produced by germination is of a different order of magnitude from the normal grain size.

Many variations in grain size can be produced in the fine-grained tungsten powder briquets by varying the rate of heating to temperatures above that of germination.[8] By heating very slowly to 3,200 deg. C., for example, an average grain diameter of 0.03 in. was produced. By heating to 2,600 deg. C. for 20 minutes and then raising the temperature quickly to 3,200 deg. C. and holding 10 minutes an average grain diameter of 0.007 in. was produced. By heat-

[11] Discussion of Papers "On Grain Growth" and "Grain Growth Phenomena in Metals"; *Trans.*, A.I.M.E., (1916), vol. 56, p. 589.

[12] "Grain Growth Phenomena in Metals," Zay Jeffries, *Trans.*, A.I.M.E., (1916), vol. 56, p. 571.

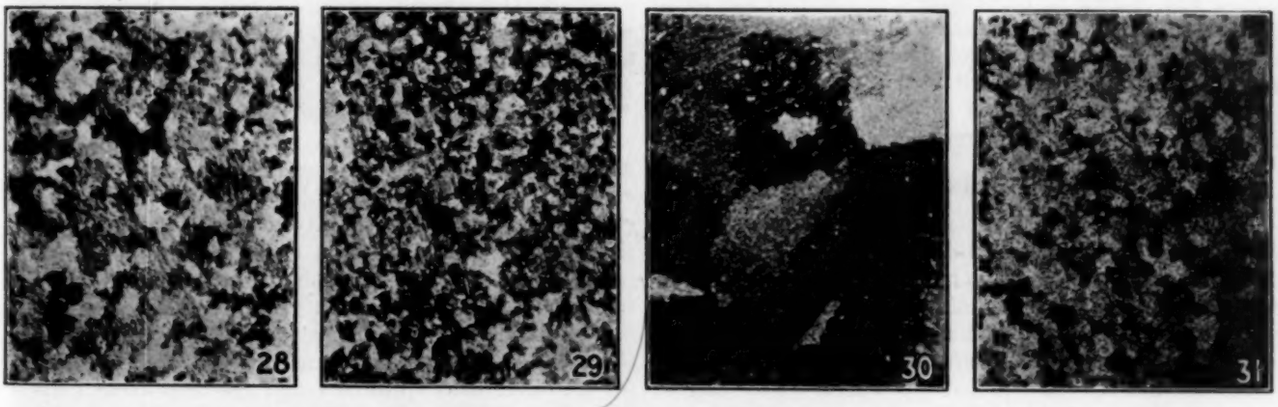
[13] Although the "normal" curves for the two grades of tungsten powder are somewhat different, the variations are not sufficient to indicate on the scale used for ordinates.

ing quickly to 3,200 deg. C. and holding 30 minutes the average grain diameter was 0.00045 in. A study of the history of the formation of the large grains always reveals the fact that in the early stages a few grains reach a size considerably larger than their neighbors. Growth is relatively slow during this stage. As the large grains become larger the rate of growth increases, provided the smaller grains remain unchanged.

When germinative conditions are encountered, rapid heating to a temperature above the germinative range is often the surest and easiest way to prevent the formation of large grains. In the few cases where large grains are desired the rate of heating is again all important.[9]

Germination can be produced in tungsten powder by incorporating the proper amount of obstruction matter (thoria) and heating to a certain temperature by the passage of electric current. Six lots of tungsten powder were prepared containing 0, 1, 2, 3, 4 and 5 per cent thoria. These were briquetted and heated for 12 minutes in an atmosphere of hydrogen at 3,200 deg. C. by the passage of electric current. A temperature gradient obtained from the axis (hottest portion) to the surface of the briquet. The resulting grain sizes produced are shown graphically in Fig. 27. Although the greater amount the grain size after solidification is very large. With still greater amounts of obstructing material the grain size again becomes small. The rate of freezing was the same in all of the tests and the only variable was the amount of obstruction material. Enlarged photographs of this series are shown in Figs. 28 to 31. Because of the "coring" tendency during freezing of solid solution type alloys, a "concentration gradient" might exist. A concentration gradient would produce a freezing temperature gradient which might promote the formation of large grains. In the examples just considered, however, the concentration gradient by itself was not sufficient to produce germination; a certain amount of obstruction was necessary. The same amount of obstruction did not cause germination in commercially pure aluminum. The striking resemblance of the 4 per cent copper series, at least qualitatively, to the series in which the thoria content was varied in tungsten will be noted.[14]

Germination may also be produced by a temperature gradient in a severely strained metal or in iron passing through the allotropic transformation. A condition of grain size contrast which leads to germination may also



FIGS. 28 TO 31. CRYSTAL SIZE PRODUCED ON SOLIDIFICATION OF Al: Cu ALLOY CONTAINING INCREASING AMOUNTS OF OBSTRUCTION MATERIAL

obstruction to grain growth is greater the greater the amount of thoria, there is a critical combination of obstruction, temperature and temperature gradient which produces a germinative condition. This series is particularly important, because it shows how the germinative temperature may be made non-existent by raising it hypothetically to a temperature above the melting point of the metal. The 5 per cent thoria sample can actually be melted without first producing large grains.

Another case of germination in drawn tungsten wire is very interesting.[9] The tungsten metal in question has a small amount of non-metallic obstruction in very small particles. The wire was drawn in the usual way, so that the strain-hardening is very great. If this wire is heated quickly to a temperature near the melting point of tungsten, a fine-grain size is produced. If, however, the temperature is raised gradually by means of an electric current, the structure is very coarse. In fact the grains usually extend across the whole cross-section of the wire and may be as much as 0.5 in. in length. These large grains form in a time not exceeding about 10 seconds. This coarse-grained structure is desirable in certain lamps to prevent undue sagging at high temperatures.

Germinative conditions are not confined to the growth of grains completely in the solid state. The present authors have found that mechanical obstruction introduced in slight amount into a liquid aluminum alloy containing 4 per cent copper produces a moderate refinement of the grain. When introduced in certain develop in a severely strained metal on heating above the recrystallization temperature. In this connection it has been observed that germination often *follows* the first structural changes on heating. For example, a strained metal may recrystallize normally and the recrystallized grains may, at a little higher temperature or on longer exposure, coalesce to form abnormally large grains. In cases of germination due to obstruction and temperature gradients there may be some growth below the germinative temperature.

One method of utilizing the principles of grain size contrast and temperature gradients to produce excessively large grains has been described by Ruder for silicon steel[15] and Schaller for tungsten. Ruder has treated a strip of silicon steel about 1 x $\frac{1}{8}$ x 14 in. in such a manner that it consists mostly of a single grain. Schaller has produced some grains about 7 in. long in tungsten wire of small diameter. The process consists essentially in starting with a material with grains so small that much growth takes place on heating. A small area of the piece of metal is heated to a high temperature in such a manner as to develop large grain locally. The piece of metal is then moved through the heated zone at a rate

[9] "Grain Growth in Metals," Zay Jeffries, *J. Inst. Metals* (1918), No. 2, p. 109.

[15] *Trans.*, A.I.M.E. (1913), vol. 47, p. 569; *J. Ind. Eng. Chem.* (1913), vol. 5, p. 452.

comparable to the rate of absorption of the small grains by the large.

Macromechanism of Grain Growth

Grain growth in the solid state takes place by the gradual absorption of some of the grains by others. This may be referred to as "boundary migration." It was formerly held by some metallographists that whole grains gradually changed orientation until two adjacent ones had the same orientation, after which they suddenly merged. The boundary did not move, according to this view, but disappeared as a boundary on account of the common orientation.

Rosenhain[14] long ago showed that growth in lead took place by boundary migration. One of the present authors[14] reported the results of an investigation showing conclusively that growth in iron took place by boundary migration. Carpenter and Elam[8] have described a most satisfactory method for studying the progress of grain growth in a tin alloy containing a small amount of antimony. When this alloy is etched and heated into the grain growth-temperature range and then cooled to room temperature, the original grain boundaries as well as the new boundaries are visible. Inasmuch as each heating and cooling reveals the new boundaries and does not efface the old ones, as many sets of boundaries as desired can be obtained. Photographs taken after each heating give a splendid record of the history of growth. Carpenter and Elam's results give additional proof that growth takes place by boundary migration.

Laws of Grain Growth

1. The grain size of cast metals is usually smaller the more rapid the rate of solidification.

2. The grain size in cast metals which undergo no phase change in the solid state cannot be changed appreciably by heating below the melting point.

3. Grain growth in the solid state may occur in (*a*) worked metals, (*b*) compressed powders, (*c*) electrodeposited metals, (*d*) in iron when it changes allotropic form and (*e*) in alloys in which a new phase is formed in the solid state.

4. The recrystallization temperature is lower (*a*) the greater the amount of deformation, (*b*) the smaller the grains prior to deformation, (*c*) the purer the metal, (*d*) the lower the temperature at which the deformation is effected and (*e*) the longer the time of heating.

5. In any given metal the grain size after complete recrystallization is normally smaller the lower the recrystallization temperature.

6. Above the recrystallization temperature the grain size is normally greater the higher the temperature and the longer the exposure.

7. The higher the temperature the more rapid the grain growth. At a temperature near the melting point a few seconds is often sufficient to produce grains which may not change further on extended exposure.

8. Certain conditions of non-uniformity sometimes give rise to the formation of abnormally large grains. This is called germination.

9. The non-uniformities giving rise to germination are: grain size contrast, strain gradients, temperature gradients, concentration gradients, and obstruction gradients.

10. The presence of foreign matter or a second phase introduces mechanical obstruction to grain growth. Resistance increases as the quantity of foreign matter or other phase increases and as the particle size decreases.

11. The presence of a certain amount of obstruction matter promotes germination.

12. The higher the germinative temperature the larger will be the grains and the quicker will they form.

13. The more rapid the heating through the germinative temperature range, at least within limits, the finer will be the grain size.

(Part III, on Underlying Causes, will be published in a Subsequent issue.)

The Non-Metallic Mineral-Filler Industry

A branch of the mining industry of which comparatively little is known, yet which has been quietly developing to meet a growing demand, is the mineral-filler industry. A discussion of the commonly used non-metallic mineral fillers and their uses in industry is given in an interesting paper by W. M. Weigel, mineral technologist of the U. S. Bureau of Mines, presented before the New York meeting of the American Institute of Mining and Metallurgical Engineers.

The term mineral filler is generally applied to a mineral used in its natural state after mechanical preparation only (such as grinding, milling and washing), without undergoing any chemical change and without exerting any chemical action on the substance with which it is incorporated. The common mineral fillers are white clay, barytes, mica, talc, whiting, ocher, silica, graphite and slate.

Sedimentary or transported white clays are the only clays used to any extent as fillers; the residual white clays, or kaolins, go to the ceramic industry. The principal centers of the clay-mining industry in the Southern district are in the vicinity of Langley, S. C., and in the central part of western Georgia. Clay as a filler is used largely in paper, rubber, oilcloth, paint, and, to some extent, in phonograph records, polishes, textiles, matches and soap. For rubber and phonograph records, the color is not important as long as it is light, but for all other uses whiteness and freedom from grit or quartz are the prime requisites.

Barytes is produced in Georgia, Tennessee, North Carolina and Alabama, Georgia ranking first and Tennessee second in production. It is used as a filler in paper, putty, textiles and phonograph records, but mostly in the paint and rubber industries. In paper, it is used mainly where a high gloss or finish is desired in supercalendered paper and in cardboard. On account of its high specific gravity its use is limited to articles for which it is peculiarly adapted. For paint and paper, fine grinding and pure white color are demanded. For the other uses, fine grinding is desired, especially for rubber, but color is of secondary importance. The content of quartz grains should be reduced to a minimum.

Whiting, the common name for finely ground marble or limestone, is one of the most widely used fillers. True whiting is ground chalk; other ground calcareous materials are substitutes. Production is now confined to Georgia, Tennessee and North Carolina. Both the dry- and wet-ground materials are used in rubber, paint, a few grades of paper, linoleum, oilcloth, shoe polish, putty, tooth powder, roofing, artificial stone and asphalt paving. Other fillers discussed are mica, graphite, talc, silica and ocher. Within the past few years the production of ground mica from schists has been developed, largely because of the rapid increase in the manufacture of ready roofing, which uses most of the low-grade material.

The German and American Synthetic-Ammonia Plants*—IV

Design and Operation of Apparatus Used for Synthesis of Ammonia at Sheffield, Ala., and at Oppau, Germany—Description of Different Processes for Removing the Ammonia—Comparison of the Costs of Construction and Production

BY R. S. TOUR

THE purified gases at Oppau enter the circulating system at about 200 atmospheres pressure, there mixing with the gases in circulation, and all pass on to the ammonia catalyst bomb for synthesis. The gas passes through three heat interchangers, two detached and one within the lower half of the catalyst bomb, after which the heated gas passes down through the catalyst bed, back through the heat interchangers, and then through a mist or dust trap, and finally goes to the ammonia absorption installation.

The ammonia synthesizers are arranged in sets, each consisting of the catalyst bomb or ammonia converter with heat interchangers and mist trap. Each set has a rated capacity of about 20 tons of ammonia per day. There are 15 such sets in the main installation at Oppau. They are arranged in a row, set partly below ground level, along, but outside of the wall of the building housing the pumps and special apparatus of the ammonia absorption and circulating systems. The valves, gages, pyrometers and other controls for the ammonia-converter sets are all located within the building. Over the row of converter sets is a protecting steel structure with a 70-ton traveling crane and between the respective converter sets is a brick wall. Thus a separate enclosure is built up for each set.

CONSTRUCTION OF THE AMMONIA CONVERTERS AT OPPAU

The following important features are to be noted in the construction of the converter itself. The shell is 3½ ft. in outside diameter and 40 ft. high, and is made up of two 20-ft. sections bolted together at the middle. Continuous throughout the length of the two sections is a close-fitting steel liner which serves to protect the pressure casing from the action of the gases. The casing is a steel forging, with wall 5 in. thick, perforated radially with ⅛-in. holes spaced about a foot apart. These serve to release gases diffusing through the liner, but allow the casing to carry all of the necessary mechanical stresses. To decrease still further the action of the gases, a later modification of the converters carries an additional liner small enough to leave an annular space between it and the outer liner, and during operation nitrogen under pressure is flushed through this space. Within the liners there is about 2½ in. of heat insulation built up of radial refractory brick. In the upper part of the enclosed chamber is the catalyst container, while in the lower is a heat exchanger. The catalyst is held in an annular space within a tube about 1½ ft. in diameter and around a 4-in. pipe leading the gas from the heat interchanger directly below to the top of the catalyst. The gas passes down through the catalyst and back through the heat interchanger.

The heat interchanger within the converter consists of a nest of about 150 half-inch, thick-walled tubes fastened into headers at each end and carrying baffle plates every few inches throughout their length, which are outside and at right angles to the tubes. This nest is placed within the converter shell in such a way as to carry the inlet gas up through the tubes and the catalyst exit gases through the baffled spaces outside the tubes. After assembling and charging the converter shell, the heads, which in reality are tapered plugs making a steel to steel seat, are forced into position by a hydraulic ram and are bolted into place with sixteen 3½-in. bolts while the ram pressure is still on. The whole bomb (catalyst and heat interchanger) is well lagged by an external insulator so adjusted that air may be circulated between the lagging and the shell for temperature control.

These complicated constructions are necessary for three distinct reasons: (1) The tensile strength, proportional limit, and the other important structural properties of steels, although slightly increasing up to a temperature of about 350 deg. C., rapidly and dangerously decrease with increase of temperature above that value. (2) Hydrogen at high temperature quite readly diffuses into and through steel and within the steel combines with carbon to form methane, which is not diffusible, thus causing blisters, blowholes and dangerous imperfections. (3) Ammonia at temperatures of formation or decomposition has a powerful action on iron, probably to break down completely its crystalline structure, probably by nitrification.

The two detached heat interchangers carry the same type of tube nests as previously described, but the shells are not built for internal heat insulation or nitrogen circulation. The casings are less than 3 ft. in outside diameter by 25 ft. high, forged in one piece and equipped with liners. The mist trap at the exit of the interchangers is of much the same construction as that described for the water scrubbers. The inlet or cooler gases pass through the heat interchangers around the outside of the tubes, while the hot returning gases pass through the tubes. This is the most efficient path.

OPERATION OF THE CONVERTERS

The catalyst bombs are charged with about 20 cu.ft. of a catalyst developed for the particular operating conditions at Oppau and consisting of practically pure iron specially prepared with an addition of some promotor. The material as used is about ½-in. mesh. Such a catalyst charge, when in use, produces about 20 tons of ammonia per day, or one ton per day per cu.ft. of catalyst. Operating at 5 per cent, this calls for a space velocity of 40,000 cu.ft. of free gas per hour per cu.ft. of catalyst, and a time of contact (allowing

*For Parts I, II and III see CHEMICAL AND METALLURGICAL ENGINEERING, vol. 26, Nos. 6, 7 and 8, pp. 245, 307 and 359, Feb. 8, 15 and 22, 1922.

33 per cent voids) of about one minute within the bed of catalyst.

The matter of the proper speed or space velocity at which to operate a catalyst is of great importance. As the speed is increased the percentage of ammonia in the exit gas is decreased, though not in as great a proportion; thus there is a greater total yield in weight of ammonia. Although this yield of ammonia controls the capacity of the catalyst, still the percentage of ammonia controls the temperature rise due to the exothermic reaction and this is the important factor in the operation of the heat exchangers and in the temperature maintenance of the system. And further, the percentage of ammonia controls the number of times a given quantity of gas must be recirculated before complete synthesis, and therefore governs the size of all the apparatus in the entire circulating system.

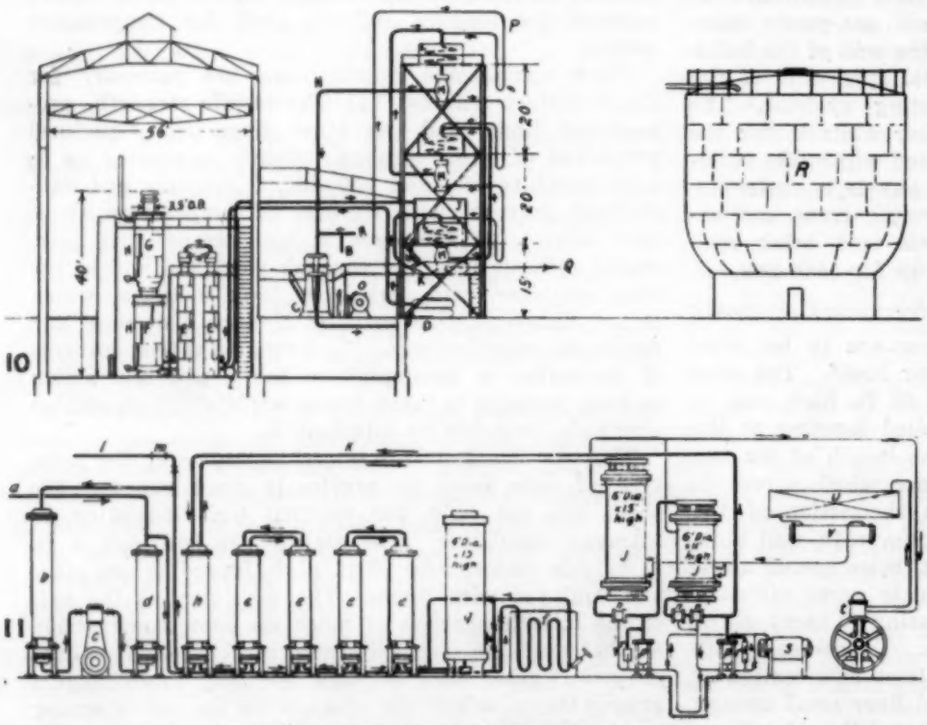
The concentration of ammonia produced at Oppau sometimes reached 5 to 6 per cent, but the general average in operation is probably about one per cent less than this figure. It is noteworthy that this represents a relatively incomplete attainment of equilibrium. The rise in temperature due to the exothermic reaction is 75 to 90 deg. C., for a concentration of 4 to 5 per cent of ammonia. This represents the heat available for maintaining the temperature of the system and also supplying the temperature head for heat interchange.

With only this small heat development the system at Oppau is no doubt not self-maintaining in temperature and addition of heat by internal combustion within the bomb is resorted to. The combustion device is also used to start the system when cold. Oxygen (or pure air) under pressure and hydrogen (or the reaction mixture) are supplied through a burner and igniter of special and very neat construction, which projects through the top of the catalyst bomb and maintains a flame in the direct path of the gases just before entering the catalyst bed. The moisture formed by combustion passes on through the catalyst with the reaction gases. One per cent of moisture by combustion will represent a rise in temperature of about 75 deg. C.

Effect of Moisture on the Catalyst

The effect of moisture on the catalyst is a point to be considered very seriously. Since at Oppau water scrubbing is used to remove ammonia from the gases after reaction, all the circulating gases carry some moisture. Saturation at room temperature calls for about 0.01 per cent by volume, but even this makes entirely unusable certain catalysts which, with dry gases, might be highly active and desirable. The type of catalyst developed at Oppau can remain in action in the presence of moisture, still its activity in such an atmosphere is greatly decreased and its operating temperature must be increased. The extent of the inhibition of catalysis depends on the moisture content. The ammonia equilibrium for 200 atmospheres pressure and 500 deg. C. calls for 17.6 per cent of ammonia, with probably 10 per cent of ammonia available from the catalyst when operating on pure gas and at the velocities in use at Oppau. Actual operation with moisture results in less than one-half this amount and further. this reaction reduces the heat generation within the bomb and the temperature head across the heat interchangers, thus making it increasingly more difficult to maintain the necessary temperature. To obviate the effect of such a cycle considerable experimenting is being done at Oppau, looking toward the development of an electrical heater to operate in place of the oxygen burner. Such a new device would have, as additional advantages, increased safety, no loss of pure hydrogen, and better temperature regulation.

In addition to the 15 converter sets, there is still available for operation at Oppau an older installation from which the present plant was developed. This consists of 8 much



FIGS. 10 AND 11. APPARATUS FOR AMMONIA SYNTHESIS AND REMOVAL AT OPPAU AND AT SHEFFIELD

Fig. 10. Ammonia converters and absorbers at German plant.
A. Purified gas inlet to circulating system.
B. Pure nitrogen for adjustment of composition.
C. Circulating compressors.
D. Water and oil traps on compressor exit.
E. Heat exchangers.
F-G. Converter bomb (F heat exchanges. G catalyst chamber).
H. Insulator and ventilator around bomb.
I. Mist trap exit converter system.
J. Cooler before absorption.
K. Mist trap exit cooler.
L. Absorbers.
M. Separating bottles after absorbers.
N. Gas return after absorption.
O. Water pumps for absorbers.
P. Water injection to absorbers.
Q. Aqua ammonia exit to storage tanks.
R. Aqua ammonia storage tanks.

Fig. 11. Ammonia converters and liquefiers at American plant.
a—Purified gas inlet to circulating system.
b—Equalizer (return receiver for unconverted gas).
c—Circulating compressors.
d—Filter. e—Heat exchangers.
f—Heater (gas fired brick furnace).
g—Converter bomb.
h—Cold exchanger.
j—Liquefiers.
k—Gas return from liquefiers.
l—Gas vent for purging system.
m—Venturi meter.
n—Separator (liquid ammonia).
p—Catch pot. r—Klinger gages.
s—Receivers (liquid ammonia).
t—Compressors—refrigeration.
u—Condenser. v—Receiver.
w—Expansion valves.
z—Suction return to compressors.

smaller converter sets, the catalyst bombs being only 1½ ft. in outside diameter by 30 ft. tall. These bombs are started by external heating applied by combustion of producer gas in a surrounding jacket. Some of this heating is also maintained during operation. This is obviously a dangerous procedure. This old installation connects into the main feeder lines and the exit manifold of the large installation, the ammonia gases passing to the next step, that of ammonia removal.

Ammonia Synthesis at Sheffield

The purified gases entered a high-pressure vessel or mixing chamber in the circulating system at less than 100 atmospheres pressure, there to mix with the gases in circulation. The mixture passed on through 4 heat interchangers, thence through a heater for starting or maintaining the temperature of the system, then through the catalyst bomb at 500 deg. C. and finally back through the heat interchangers.

There was but one set of interchangers and catalyst bomb in the operating unit (Unit No. 1) at Sheffield and this was located in the same building as the purification apparatus and equipment. The ammonia converter itself consisted of a chromium-vanadium forging 4 ft. in inside diameter, 15 ft. high, with walls 3 in. thick. Within this shell was a nest of ninety 2-in. boiler tubes, which were to be charged with 50 cu.ft. of catalyst. The gas entered at the bottom of the shell, passed up around the tubes, then down through the catalyst and out at the bottom of the shell. The heads of the converter were designed to make a special type joint with the shell, making use of the internal pressure to keep the joint tight; this device, however, proved troublesome and unsuccessful. Otherwise the entire construction was very simple compared to the bomb at Oppau. Within the converter, no arrangement was made to protect the bomb from the action of the gases, or to keep it cooler than the operating temperature.

The heat interchangers consisted of forged steel shells 2 ft. in inside diameter, 14 ft. high, with 3-in. walls. Within each shell there was a nest of tubes of very special construction. Each tube element of the nest consisted of 3 concentric tubes, thus having two annular spaces between them. The two gas flows interchanging heat passed each other through these annular paths. No use was made of the volume around the tube elements. This arrangement is ingenious and leads to a high coefficient of heat transfer per unit of transfer surface, but also leads to high friction per unit of heat transferred. Larger apparatus per unit of transfer surface is also required. By a system of valves in the interconnections between interchangers, any one of the interchangers could be bypassed during operation.

Heating of the Gas

A heater, similar in type to a standard steam superheater, was situated so as to heat the circulating gases just before they entered the catalyst bomb. The gas flowed through a series of high pressure tubes connected with flanged joints in a gas-fired furnace of three passes. This heater was the source of much trouble due to bursting tubes and leaking joints and prevented any continuous testing of the circulating system as a whole. This type of heating is subject to two inherent objections: (1) The heat transfer surface must operate at a high temperature and at the same time retain its strength. (2) The efficiency of a furnace furnishing heat at such a high temperature level is necessarily very low. These two objections can be overcome only by internal heat application, which can be accomplished in two ways: (1) Internal combustion of hydrogen by injection of oxygen, and (2) electrical resistance heating directly in the gas path. These have been discussed somewhat under the Oppau description. Electrical heating during Sheffield operation could not have been more expensive than the method in use.

During attempted operation, the catalyst bomb was charged with a special catalyst "composed of iron, sodium and nitrogen." During the development of this catalyst, laboratory experiments with pure gas had indicated that at a space velocity of 5,000 cu.ft. of free gas per cu.ft. of catalyst about 8 per cent of ammonia might be expected in the gas. This catalyst was especially sensitive to poisons, and traces of oxygen-carrying impurities such as O_2, CO_2, H_2O, and CO permanently and rapidly deteriorated its activity. Such a catalyst may be highly active on pure gas, but commercial operation can not be expected to maintain the necessary purity of gases. In fact, at Sheffield, it is doubtful if the desired purity was ever obtained. Operation was so intermittent that statements as to the actual percentage of ammonia converted by the catalyst would be misleading.

Ammonia Removal at Oppau

The ammonia content of the gas is removed by water scrubbing the gas without releasing its pressure, the remaining gas recirculating while the absorbing water is discharged as aqua ammonia. The gas mixture with 4 to 5 per cent of ammonia leaves the converter sets and passes to a main which feeds 8 absorber sets, located on the outer side of the pump house building and opposite the converter sets. In order to secure more favorable temperature conditions for absorption each set first passes the gas through a cooler of 12 coils in parallel, thence to a mist separator and on to the elevated water absorbers. There are 3 absorbers in each set placed one above the other at 20-ft. levels. Each absorber consists of 12 spiral concentric coils connected in parallel, and submerged in a water bath in order to take up the heat of solution generated within the coils. At the exit of each absorber is located a trap to separate the gas and liquid. The water flows downward through the set of absorbers as a whole and the gas upwards, the absorption taking place in three stages, with separation of gas and liquid between stages. In the uppermost stage (third gas and first water stage) water is injected with the gas and the mixture of gas and liquid flows downward through the coils by gravity. The solution from the third gas stage after separation feeds downward to the second and then on to the first. The gas from the first and lowest stage flows to the entrance of the second stage, then on to the third. This arrangement affords a counter supply of solvent although the necessary parallel flow is obtained within the coils of each stage. A newer type of absorber has been installed and used for the last stage of one set of absorbers. This consisted of towers similar to those used in the cuprous formate scrubbing system and provided true counter-current flow at least in the last stage of absorption.

There are 6 steam-driven water pumps (totaling about 800 hp.) for the absorbers. This pump capacity will furnish sufficient water to the absorber sets to give as a final product commercial aqua ammonia of a strength of 25 per cent. Considerably less water

may be used and solutions of much higher strength obtained, but upon release of pressure these evolve gaseous ammonia and leave a 25 per cent aqua. The solution leaving the last separator of the absorber system is discharged to high pressure ammonia receivers, which in turn are discharged when full into closed low pressure reservoirs. Considerable nitrogen and hydrogen gases are dissolved in the aqua and these, released in the reservoirs, are washed with a counter current flow of water to remove ammonia and are returned to the gas holder just previous to the compression stages of the process. The aqua ammonia is finally stored in three large tanks of about 750,000 gal. capacity each.

The high pressure gas in passing through the absorber system gives up most of its ammonia to the water, only about one-fourth of one per cent remaining in the gas. This ammonia content will depend on the temperature at which the last gas stage of absorption was maintained and on the ammonia concentration of the aqua emerging from this last stage together with the gas. Evidently the more water used for absorption the less is the residual ammonia in the gas. However, the hydrogen and nitrogen dissolved and the power required will increase with the increase of water and this represents some small loss in the efficiency of the system.

Ammonia Removal at Sheffield

The intention at Sheffield was to remove the ammonia from the gas by refrigeration at temperatures of —30 or —40 deg. C.; the ammonia was discharged as liquid anhydrous ammonia, while the residual gas was to recirculate back to the converter set. There were two ammonia liquefiers in the installation, each consisting of 7 spiral concentric coils fed from a common manifold and discharging into a common manifold. Inclosing these spirals was a shell 6 ft. in diameter by 15 ft. high, in which the necessary refrigeration was maintained. A standard-type ammonia installation furnished the refrigeration, the ammonia from the condensers expanded directly into the liquefier shells, and the compressors withdrew the evaporated ammonia from the top of the shells. The two liquefiers operated in series on the high pressure gas, although the refrigeration on the outside of the coils operated in parallel in the two shells. The high pressure gas on leaving each of the liquefier coils passed through a mechanical separator where the liquefied ammonia was separated and drained to a pot while the gas passed on through the separator, and thence to a cold interchanger. This apparatus was identical with the heat interchangers previously described and served to cool the incoming gases to the liquefiers by means of the cold gases leaving the system.

To maintain temperatures of —30 or —40 deg. C. it is, of course, necessary to expand the refrigerating ammonia to a considerable vacuum and it is required that the refrigerating compressors operate at that vacuum on the suction stroke. This, in turn, means that the compressors have a much smaller refrigerating capacity in view of the large volume of the refrigerant. It was soon found at Sheffield that although the compressors had the necessary rated refrigerating capacity when operating to make ice under commercial conditions, still they had less than 20 per cent of the refrigerating capacity necessary for the ammonia removal. Additional compressors were, therefore, at once moved over from Units 2 and 3 at Sheffield, together with all spares, and all were connected in the line for operation in Unit No. 1.

The operation of single-stage ammonia compressors with ratios of compression of the order of 20 to 1 must, in general, lead to serious inefficiencies and mechanical difficulties. The operation of two liquefiers in series on the gas with refrigeration on each at the same low temperature level is also inefficient. The first liquefier in the series could be operated to advantage at a higher temperature level and leave only the second liquefier to meet the low temperature requirement. The Nitrate Division in its redesign of the Sheffield plant has laid out a simple installation with standard equipment to operate with compound compression of refrigerant for the low temperature liquefier while the first liquefier operates within a nearly normal ice making cycle.

The total refrigerating capacity may be considerably reduced, although the problem is not greatly simplified where ammonia liquid is not the necessary product of manufacture. In such cases the condensed liquid leaving this high pressure system may be expanded into a liquefier shell, thus effecting considerable refrigeration. This refrigeration would be necessarily independent of the main refrigerating installation in view of the gases dissolved in the synthesized ammonia.

Separation of Condensed Ammonia

The separators for removing the condensed ammonia from the high pressure gas at Sheffield consisted primarily of a vertical baffle plate at right angles to the horizontal flow of ammonia laden gases. No data were obtained as to the efficiency of these simple separators, but general indications were that the ammonia removal was incomplete. The separated ammonia drained from the separator into a high pressure receiver from which it was discharged at intervals into liquid ammonia reservoirs.

The removal of the condensed ammonia from the high pressure gas is a subject requiring serious consideration. Much of the ammonia condenses in the gas as a fine mist difficult to precipitate or agglomerate into larger particles for separation. These in turn are difficult to separate from the gas stream. An analogous but much simpler case is the separation of water from wet steam, which is accomplished in the industry by various types of apparatus, all of which depend on the difference in specific gravity between the suspended water and the steam. In the latter case, ordinary practice involves a ratio of specific gravities of the order of 150 to 1, whereas in the case of removing ammonia from the high pressure gas the ratio is but one-tenth as great. In view of the low specific gravity ratio, high velocities are probably essential in mechanical separation. Other requirements, no doubt, are low friction of the gas stream over the separating surfaces, and immediate removal of the separated liquid from contact with the gas. All the above has been kept in mind in the development by the Nitrate Division of an ammonia separator for use at Sheffield should the plant ever again operate.

The Germans, in developing their process, had seriously considered and experimented with refrigeration as a means of ammonia removal, but they finally turned to water absorption as the easiest solution of the problem. In so doing, they gave up several distinct advantages of refrigeration: (1) Circulation of pure dry gases in which desiccation is maintained by the precipitation of anhydrous ammonia within the gas.

(2) Production of pure anhydrous ammonia is accomplished without any further steps of distillation. The first of the above is the most important in view of the fact that moisture in the system decreases catalytic activity and reduces the capacity of the entire installation, as has been previously discussed. The second is important only in connection with the utilization of the ammonia. On the other hand, water absorption of ammonia has the advantage of practically complete ammonia removal, and decided reduction in power consumption.

Circulating System at Oppau

The gas is circulated through the converter sets and through the absorption system by 10 double-acting circulating pumps. These are steam driven and direct connected at 90 deg; the pump cylinder is vertical and the steam cylinder horizontal. In normal operation the differential pressure necessary to circulate the gases is about 5 atmospheres, though it has, at times, risen to 10. The circulating pumps are located in the cycle just after the absorbers and ahead of the converter sets. At the inlet side of the circulating pump the pure make-up gas is added and also the composition of the gas in circulation is adjusted by the addition of the pure nitrogen that was spoken of earlier in this paper.

The question frequently arises as to whether it is desirable to have the circulating pump precede or follow the point in the system where the make-up gases are added. In the latter case, the pump must directly handle the volume of make-up gas, together with the volume of circulating gases. However, the total pressure of the circulating system is higher by the amount of the differential pressure, since the pressure of the make-up is fixed by the pressure of the purification system. The pressure desired in the circulating system should determine the location of the circulating pump; the total quantity of energy expended is but slightly different in the two cases.

The speed of circulation of the gases as it affects the catalysis of the ammonia has been discussed in connection with space velocity under ammonia synthesis. For a given installation, operation may develop any one of the following limitations to increase the speed of circulation: (1) Insufficient heat transfer to maintain the temperature of the ammonia converter sets, (2) insufficient capacity of the purification system to supply the necessary gas for the increased yield, (3) insufficient capacity of the ammonia-removal installation to take care of the increased yield, and (4) excessive friction to gas flow in the apparatus of the circulating system. These general engineering aspects of the process are of fundamental importance, but their discussion is not within the purpose of this paper.

Inert Gases

The inert gases, methane and argon, are present to the extent of 0.5 to 0.7 per cent in the make-up entering the circulating system at Oppau, and tend to accumulate as the hydrogen and nitrogen are being removed in the form of ammonia. Some method of removal of this accumulation must be employed. The simplest method for continuous operation is to allow a fraction of the circulating gases to escape continually. Purging a quantity of gas from the circulating system equivalent to 5 per cent of the entering make-up gas will maintain a concentration of inert gases of 20 times that in the make-up. Likewise, 10 per cent purge will allow a concentration of 10 times that entering the system. The effect of inert gases on the catalysis of ammonia is very decided due to the lowering of the equilibrium, but on the other hand, the loss of purified hydrogen and nitrogen in the purge is costly, although the hydrogen may be burned under boilers. In operation the choice as to the proper purge is generally fixed by the unavoidable leakage in the system. Thus, at Oppau, this was never below 10 per cent of the makeup gas, therefore the concentration of the inert was never above 5 to 7 per cent and no additional purge was necessary.

Circulating System at Sheffield

At Sheffield the gas exit from the liquefiers passed to the circulating pumps, the make-up gas connecting in at the exit of the pumps. The circulating pumps themselves were vertical, double acting, motor driven, but due to the sensitiveness of the catalyst, were not lubricated and therefore not equipped with piston rings.

This led to rather low volumetric efficiency. The pumps had been designed for a maximum differential of 50 lb. Due to the many right-angle elbows and tees, numerous valves, and the special construction of the heat interchangers, the friction in the system accumulated to 150 lb. and still less gas was circulated than was necessary. This caused considerable difficulty with the pumps and their motors. Engineering experience offers very little information for the calculation of friction of gas flow under the conditions existing in the synthetic ammonia process. Some preliminary experiments conducted by the Nitrate Division indicate that it varies with the square of the velocity and therefore that a formula of the standard type may apply.

There are no facilities for adjustment of composition in the circulating system at Sheffield, but during operation such adjustment was found unnecessary in view of the high losses, which at times amounted to 50 per cent. These losses of course prevented accumulation of either hydrogen or nitrogen in the system, as well as accumulation of the inert gases.

The pipe connections throughout the system were all made up with copper gaskets, which worked very satisfactorily where there were no undue strains on the joints. The apparatus in the circulating system was arranged very closely and there was no allowance for the expansion due to the extreme range of temperature. The strain thus set up always developed leaks. There were many valves in the heat interchanger connections and in other hot parts of the system and although these valves were water cooled, still the differential expansion between the stem and the block caused difficulties. Operation on this portion of the system was, however, so intermittent and of such short duration that no opportunity was given to cure the difficulties encountered, although the matter has been taken up with great care in the redesign of the plant and in the development of joints and valves.

The last installment of this article, in which the costs of construction and production at Oppau and Sheffield are compared, will be published in a subsequent issue.

Heat Balance in Coal Distillation

An investigation to determine the amount of heat evolved or absorbed through chemical reaction in the destructive distillation of coal is being conducted by the Bureau of Mines. Such information will give the by-product coking and gas industries a more accurate knowledge of the thermal requirements of their ovens and retorts.

Explosion-Proof Process of Solvent Recovery

Descriptive Study of Lewis Recovery System in Which the Explosion Hazard Is Eliminated by Using Cleaned Flue Gas as the Drying Medium—Theoretical Consideration of the Relation Between Recovery and Recirculation in the Condensation-Recirculation Process

BY B. F. DODGE
Chemical Engineer

ONE of the strongest objections to the use of flammable solvents in industrial operations and to most of the solvent recovery processes is the fire and explosion hazard. In many of the processes proposed or utilized in the past an attempt has been made to keep the average concentration of the solvent vapor in the air-vapor mixture outside of the explosive range. This is generally unsatisfactory and many such attempts have resulted in disaster. To keep the concentration below the explosive range means that a large amount of gas must be handled which is very dilute in solvent vapor. It is well known that the installation costs and operating costs of a recovery plant increase rapidly as the concentration decreases. Furthermore, unless extreme care is exercised in the design of the ventilating equipment, pockets are apt to form where dangerous concentrations are present. On the other hand, attempts to work above the explosive range almost always result in failure, because it is inevitable that somewhere in the recovery plant the explosive range is being passed through and furthermore the explosive range must be crossed in starting or stopping the operation by which the drying of the goods is performed.

It has long been recognized that this hazard could be overcome by replacing the air as a carrier by some inert gas such as nitrogen or carbon dioxide. The cost of producing such a gas, however, has militated against its use. This objection has been met by a process developed by Dr. W. K. Lewis of the chemical engineering department of the Massachusetts Institute of Technology, who has used a cleaned flue gas as the inert drying medium. Lewis pointed out that it is only necessary to remove part of the oxygen from the air to make a good inert gas, and the simplest way to remove oxygen from air is to allow the oxygen to react with carbon or hydrocarbons as in an ordinary combustion reaction. Consequently, by the term "flue gas" is meant any gas produced by depleting the oxygen of the air by reaction with carbon or hydrocarbons.

Before referring to the process itself, it may be well to discuss briefly the flammability of gas mixtures, in order to show that the presence of flue gas prevents explosion even though a considerable percentage of oxygen may be present.

Limits of Flammability of Gas-Air Mixtures

It is a well-known experimental fact that mixtures of so-called flammable gases with air are only flammable between certain definite concentration limits. This does not mean of course that they will not burn if heat is continuously supplied from an external source, but rather that they will not support combustion of themselves. The experimental determination of the upper and lower limits is difficult because of the many factors involved. The results that appear in the literature vary, but in Table I are given the limiting values for some common gases, expressed as volume per cent of the gas.[1]

TABLE I—FLAMMABILITY LIMITS OF SOME COMMON GASES AND VAPORS, EXPRESSED AS PER CENT BY VOLUME.

Gas	Lower Limit	Upper Limit
Hydrogen	8.5— 9.5	66.3—75.5
Methane	5.5— 6.3	12.7—13.5
Ethylene	3.4— 4.1	14.5—14.6
Ether	1.6— 2.8	7.5— 7.7
Alcohol (C_2H_5OH)	3.7— 4.0	13.6—13.7
Benzene	1.4— 2.5	6.3— 6.5
Pentane	1.3— 2.4	4.8— 4.9
Carbon monoxide	14.3—16.5	74.0—75.0

Oxygen is, of course, necessary for the explosion of a gas mixture, and consequently explosions can be entirely prevented by replacing the oxygen by some inert gas such as carbon dioxide, carbon monoxide, nitrogen or mixtures of them. A very important corollary of this is that it is only necessary to replace a part of the oxygen to obtain a non-explosive mixture and the permissible per cent of oxygen is surprisingly large. For example, it is found experimentally that, with a mixture of methane and air, if the oxygen is reduced to 13 per cent by replacing part of it with carbon dioxide, no ex-

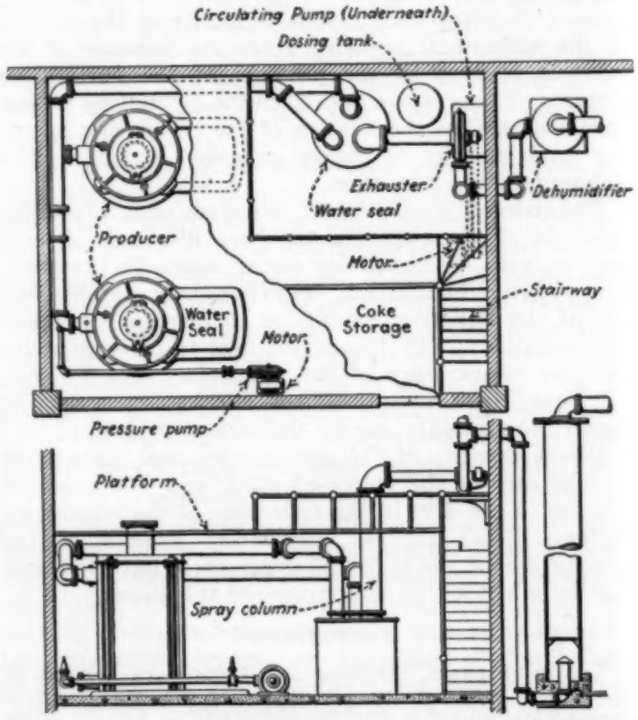


FIG. 1—LAYOUT OF PLANT FOR PRODUCING THE FLUE GAS FROM COKE

[1] "Untersuchungen über die Explosions Grenzen brennbarer Gase und Dampfe"—Paul Eitner.

plosive mixture is possible with any percentage of methane. On the basis of the theory of flammable limits, we are able to calculate the permissible per cent of oxygen for a number of gases. Without going into the details of the theory it may simply be stated that no explosive mixture of gasoline or of benzene and air is possible if the oxygen is maintained below about 12 per cent.

Producing the Inert Gas

The inert gas is cheaply produced by burning coke in a special type of producer or by burning fuel oil in a small brick oven. The gas from the producer or oven, consisting mainly of carbon dioxide, nitrogen and water

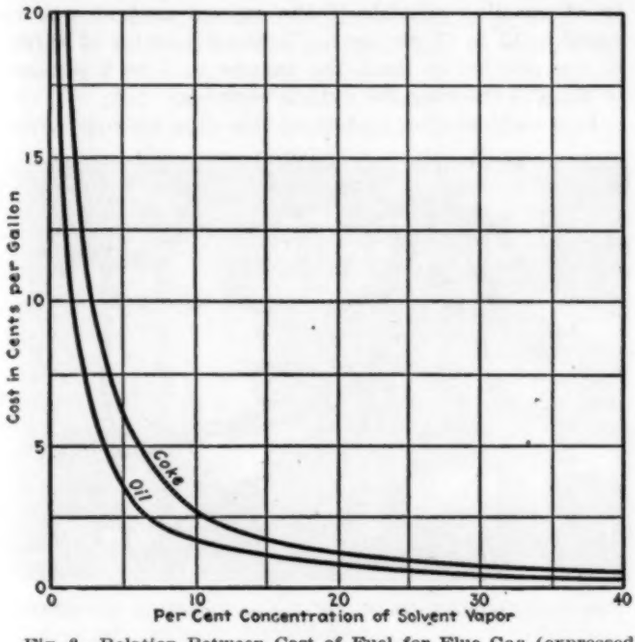


Fig. 2—Relation Between Cost of Fuel for Flue Gas (expressed as cents per gallon of solvent recovered) and the Concentration of the Solvent Vapor (expressed as volume per cent).

vapor, is cooled, cleaned and dehumidified in a spray chamber or coke tower, after which it is ready for use as the solvent drying medium. If the oil or coke is high in sulphur, it may be necessary to include a scrubbing outfit to remove sulphur dioxide. The choice between coke or oil is largely an economic question depending on their relative cost, as either will yield a clean gas of low oxygen content (0 to 2 per cent). Fig. 1 shows a layout of a plant for producing the gas using coke as the fuel.

The reaction of air with coke can be controlled to produce either carbon dioxide or carbon monoxide as desired. In producer gas practice, carbon monoxide is the main product desired, but for use as an inert gas, carbon dioxide is the more desirable. A study of the equilibrium relations among carbon, carbon dioxide and carbon monoxide and of the rates of reaction shows that the conditions for maximum carbon dioxide production are low temperature of the fuel bed, a shallow bed (as shallow as is consistent with no air holes) and a fairly low velocity of gases through the bed. The producer should be set in an iron shell to reduce the inward leaking of oxygen if run under suction, or outward leakage of gas if under pressure. With proper design of the producer and proper control of the firing and draft, a gas can be consistently produced that contains 18 to 20 per cent of CO_2 and 0.1 to 1.5 per cent of O_2.

The use of flue gases from an ordinary boiler is not desirable because of the high and fluctuating oxygen content and the presence of soot, which is difficult to remove in a simple manner. The use of coke gives a gas that is practically free from finely divided solid or liquid particles, and an oil burner can be operated in such a way as to give a clean gas with a low oxygen content. In small installations the recovery of the heat in the flue gases does not pay, but for large installations it is sometimes advantageous to generate the flue gas in a coke-fired or oil-fired boiler, although bearing in mind that the primary object is the generation of the inert gas.

It can readily be calculated that 1 lb. of coke and 1 gal. of fuel oil will yield about 120 cu.ft. and 1,600 cu.ft. respectively of dry gas at 70 deg. F. The cost of the flue gas per gallon of recovered solvent is a function of the concentration of the solvent vapor that can be obtained in the gas, and since the latter is relatively high in most cases, the cost is practically negligible. Fig. 2 gives a comparison of calculated fuel costs to produce the gas, assuming coke at $18 a ton and fuel oil at 7c. a gallon. The cost can be reduced and the recovery increased by the simple expedient of recirculating part of the flue gas from the recovery plant.

Application to Various Processes of Solvent Recovery

The gas may be applied to any compression, refrigeration or absorption process of solvent recovery without any change in the recovery equipment. The recovery obtained is just as high as when air is used as the medium.

In using flue gas it is necessary that the drying operation be carried out in a well-inclosed space so that

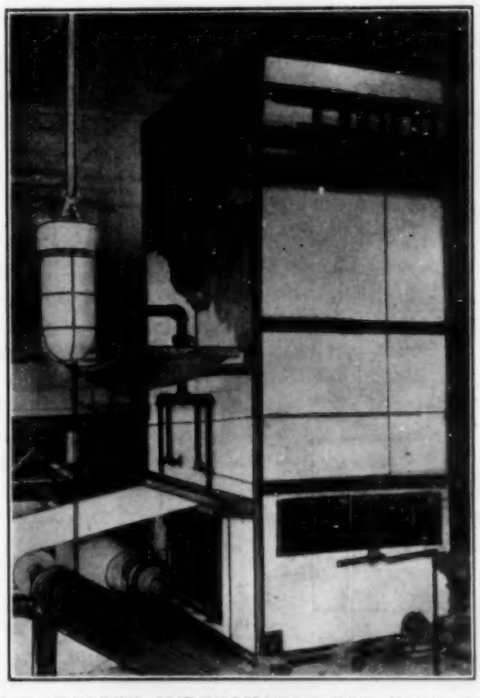


FIG. 3—HOODED IMPREGNATOR FOR CORD TIRE FABRIC IN ACTUAL USE

leakage of air in, or of the flue gas out, will be a minimum. This has led to the development of efficient hoods for various machines in which solvent is used, with the result that greater production has been attained, the operators are effectually shielded from the injurious ef-

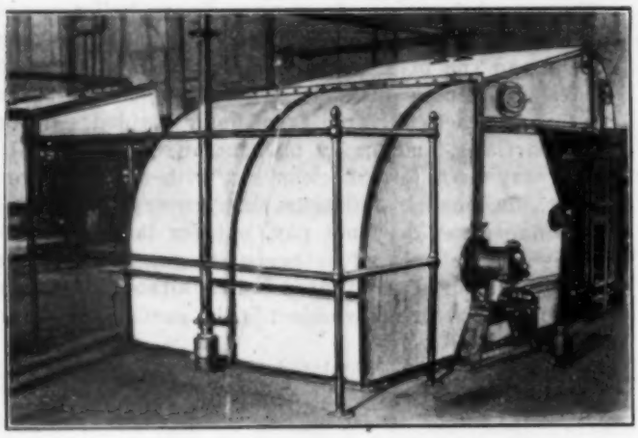


FIG. 4—DRUM SPREADER EQUIPPED WITH HOOD FOR USING FLUE GAS PROCESS OF RECOVERY

fects of solvent fumes. Furthermore, the better control of the drying conditions results in a more uniform product. To treat further of this very important phase of solvent recovery is beyond the scope of this article. Attention is called, however, to Figs. 3, 4 and 5. Fig. 3 shows a hooded impregnator for cord tire fabric and Figs. 4 and 5 show the types of hoods that have been applied to drum and flat spreaders used for the rubberizing of fabrics. Figs. 4 and 5 are rear and front views respectively of a hooded drum spreader.

Condensation-Recirculation Process Using Flue Gas

The method of solvent recovery based on condensation in a water-cooled condenser followed by recirculation of the gases leaving the condenser to the point where the solvent is being evaporated can be shown to possess a number of advantages, particularly as regards initial cost of equipment and operating and maintenance charges. The commercial development of this method has been retarded by two factors—viz., (1) the difficulty of obtaining sufficiently high concentrations, and (2) the fire and explosion hazard. The first difficulty has been met by the design of efficient hoods as discussed above, and the second by the use of flue gas as the carrying medium for the solvent vapors.

With a recirculation system of this type it is impossible to recirculate all the gas leaving the condenser, if the solvent-using operation is a continuous one, because small leaks will occur where the material being treated enters and leaves the drying chamber. In the development of this process the main problem was to determine if enough of the gas could be recirculated to give a high recovery without allowing the oxygen content to become high enough to introduce any explosion hazard. This process was first studied from a theoretical standpoint and found to be feasible, after which the theory was substantiated on a plant scale.

A study of the effect of inert gas on the flammability of gas mixtures established the fact, as previously shown, that there was no explosive mixture of benzene or of gasoline possible if the oxygen content was reduced to 12 to 13 per cent. To allow a factor of safety, it was decided to limit the oxygen to 5 to 6 per cent in the gas entering the drying chamber.

In a recirculation system of this type an equilibrium

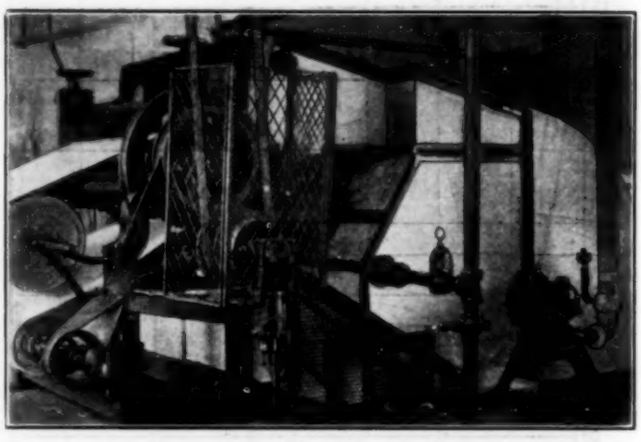


FIG. 5—ANOTHER VIEW OF HOODED DRUM SPREADER IN USE

oxygen concentration will be attained when just as much oxygen is being purged from the system in a unit of time as is entering the system. Consequently, the main factors affecting the per cent of permissible recirculation will be the amount of leakage in or out of the system, the amount of oxygen in the fresh "make-

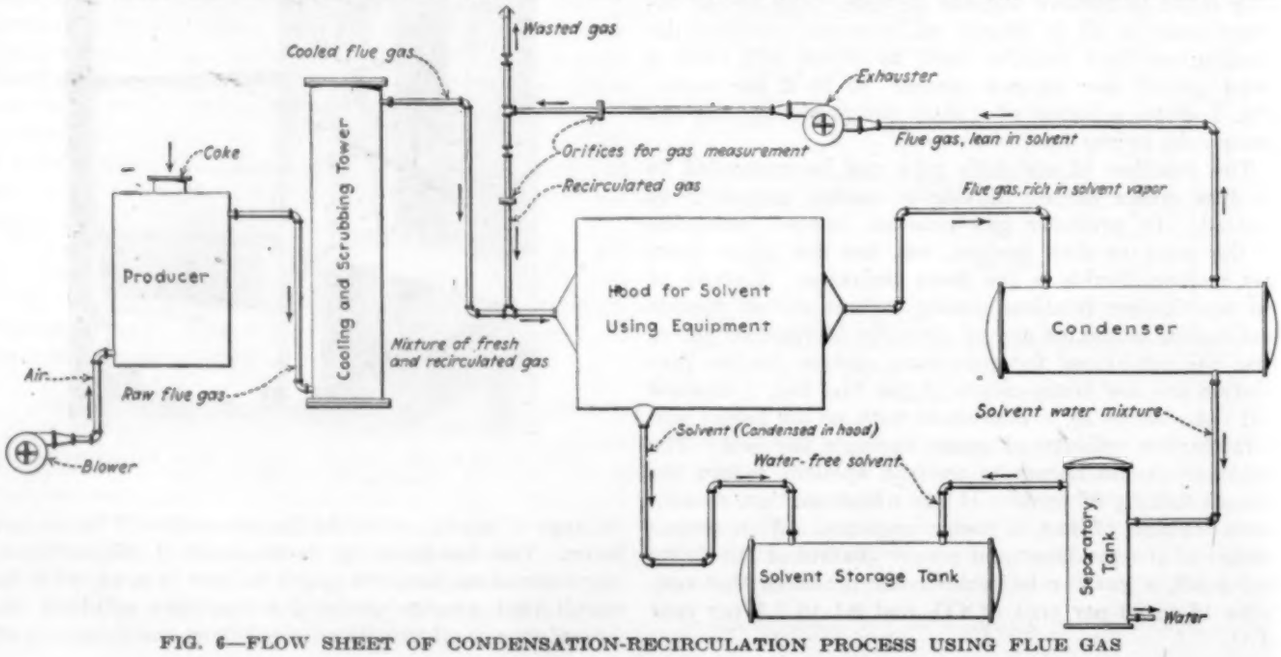


FIG. 6—FLOW SHEET OF CONDENSATION-RECIRCULATION PROCESS USING FLUE GAS

up" flue gas, and the permissible oxygen in the system. All the leakage will occur in the hooded drying chamber and the assumption was made that practically all the leakage was inward. On this basis a general equation for recirculation may be developed. Reference to the flow sheet of the process, shown in Fig. 6, will aid in understanding the factors involved.

Developing an Equation for Recirculation

Solvent is being evaporated under a hood, which is assumed for sake of illustration to be inclosing an equipment for impregnating a fabric with a rubber compound. Some air leaks into the hood at the point of entrance and exit of the fabric. The flue gas, rich in solvent, goes to the condenser, where part of the solvent is condensed. The gas, now lean in solvent but containing very appreciable amounts, divides, as shown, into two portions. One portion is recirculated back to the hood, receiving an addition of fresh flue gas as shown, and the other portion is wasted to the atmosphere. It is desired, of course, to recirculate as great a fraction of the gas from the condenser as possible, but this is limited by the leakage and the permissible oxygen content. The following quantitative treatment of the problem was a valuable aid in predicting the result of large-scale experiments:

Let f = fraction of the gas recirculated.
O_r = fraction of oxygen in the recirculated gas.
n = mols of air leaking into the hood per mol of total gas fed to the hood.
O_g = fraction of oxygen in the fresh flue gas.
s = fraction of solvent in the gas leaving the condenser.
m = mols of gas leaving the condenser per mol of gas fed to the hood.

Then, on the basis of 1 mol of total gas fed to the drying chamber,

mfO_r = mols oxygen recirculated.
$mO_r(1 - f)$ = mols oxygen purged from the system.
$(1 - mf)$ = mols fresh flue gas.
$O_g(1 - mf)$ = mols oxygen entering with the fresh flue gas.
$\frac{n}{5}$ = mols oxygen leaking in.

Equating the input and output of oxygen we obtain:

$$\frac{n}{5} + O_g(1 - mf) = mO_r(1 - f) \qquad (1)$$

m is best expressed as a function of the other factors in the following manner:

In m mols of gas leaving the condenser there are $(1 - s)m$ mols of non-condensible gas which is made up of the non-condensible gas recirculated, plus the air leaking in, plus the fresh flue gas.

In the mf mols of gas recirculated, there are smf mols of solvent. Therefore, there are $(1 - smf)$ mols of non-condensible gas entering the drying chamber.

Equating the non-condensible gas leaving the condenser to that leaving the drier, we obtain:

$$(1 - s)m = 1 - smf + n$$

or,

$$(1 - s)m + smf = 1 + n$$

and,

$$m = \frac{1 + n}{1 - s + sf}$$

Substituting this value of m in (1), the equation becomes

$$\frac{n}{5} + O_g\left[1 - \frac{f + fn}{1 - s + sf}\right] = \frac{O_r(1 - f)(1 + n)}{1 - s + sf}$$

Solving for f, we obtain:

$$f = \frac{O_r + O_rn + O_gs - O_g + \frac{ns}{5} - \frac{n}{5}}{\frac{ns}{5} + O_gs - O_g - O_gn + O_r + O_rn} \qquad (2)$$

The approximate value of the per cent recirculation for a wide variety of conditions can be predicted by substituting in this equation. It is found, in this way, that a fairly large percentage variation in the oxygen content of the fresh flue gas has only a small effect on the recirculation whereas variation in the leakage seriously affects the recirculation.

Table II gives the results of some calculations made with the aid of equation (2).

TABLE II—PERCENTAGE RECIRCULATION AND PERCENTAGE RECOVERY CALCULATED FOR DIFFERENT VALUES OF O_r AND n

Case I. $n = 0.10$, $O_g = 0.01$, $S = 0.12$, O_r variable				Case II. $O_r = 0.05$, $O_g = 0.01$, $S = 0.12$, n variable			
$O_r \times 100$	$f \times 100$	Per Cent Recovery		$n \times 100$	$f \times 100$	Per Cent Recovery	
		*A**	*B*†			*A*	*B*
2	0	70	20	2	91	97.3	92.8
3	27	78.1	41.6	5	79	93.7	83.2
5	60	88.0	68	10	60	88.0	68.0
7	73	91.9	78.4	20	30	79.0	44.0
10	82	94.6	85.2	25	17	75.1	33.6

*The concentration of solvent vapor is assumed to be such as to give a 70 per cent recovery by simple condensation without recirculation.

†The concentration of solvent vapor is assumed to be such as to give a 20 per cent recovery by simple condensation without recirculation.

Referring to Case I in the table, it is seen that the percentage recirculation is greatly influenced by the allowable percentage of oxygen in the recirculated gas, increasing rapidly as the oxygen is raised. If the concentration of solvent vapor is high, say over 35 per cent, the percentage recovery is good even with a small recirculation, but if the concentration is as low as 15 per cent a higher percentage recirculation must be maintained to obtain a good recovery.

Case II shows the effect of leakage on the percentage recirculation, the other factors being fixed. As would be expected, the allowable percentage recirculation ($f \times 100$) becomes rapidly lower as the leakage increases. This in turn affects the recovery, and again the effect is much more marked for the case of low concentration of solvent vapor (B) than for the case of high concentration (A). It is obvious that the process can be applied only to cases where concentrations of solvent vapor may be obtained that are appreciably greater than the equilibrium concentration at the temperature at the exit of the condenser, which means that the solvent must be evaporated at a temperature well above room temperature.

In one case to which this process was to be applied —namely, the impregnation of cord tire fabric—O_r was chosen to be 0.05 (5 per cent of permissible oxygen in recirculating gas), n was assumed to be about 0.1 on the basis of the leakage tests that were available, O_g could easily be kept to 0.01 and s was about 0.12. Substituting these values in equation (2), $f = 0.60$. In other words, 60 per cent recirculation could be used under these conditions. Inasmuch as about 80 per cent recovery is obtained in the simple condenser without recirculation, the total recovery with recirculation should be $80 + (0.60 \times 20) = 92$ per cent, or nearly as much as could be obtained with a more complicated equipment. It was found in actual practice that between 60 and 70 per cent recirculation could be used under approximately these conditions, thus bearing out the value of the preliminary theoretical study. The leakage is actually less than 0.1 on the average, and it seems probable that about 75 per cent to 80 per cent recirculation can be used with a well-designed hood.

Lewis Recovery Corporation,
Cambridge, Mass.

Legal Notes

By Wellington Gustin

Chemical Company Liable for Death of Horses Where It Filled Dedicated Street With Refuse

In the action by Harry Shapiro against the Albany Chemical Co., it was shown that the chemical company had dumped a tarry and caustic material into the street adjoining its property in such a manner that its nature was not apparent. The plaintiff's horses, while being driven along such street, became mired in the material, where it had a depth of about 5 ft., causing the death of the animals. The company was sued for negligence and damages were recovered. (189 N. Y. S., 736.)

On appeal the Appellate Division of the New York Supreme Court confirmed the company's liability. It says where a city extended its conduit through a street, dedicated as a public street but never accepted as such, with consent of the chemical company abutting thereon, and not claiming to own the street, which extension involved the use of the street to a greater or less degree, the company, which filled the street with a tarry and caustic material carried in a pipe from its works, is liable to an employee of the city for death of his horses, which became mired in such material when he was directed to go on the premises and remove a pump. The company was under obligation to exercise its right in the street consistently with the fact that it had been dedicated for public use, and that title to adjoining property had passed on the strength of that condition.

Circuit Court of Appeals Affirms Decree Holding Wooster Patent No. 933,011 Void

The United States Circuit Court of Appeals recently affirmed the decree of the District Court in the matter of the Duryea Manufacturing Co. vs. Agrippa Manufacturing Corporation and others, whereby the Wooster patent, No. 933,011, was held void for anticipation by the old Pearce & Beardsley patent by about 25 years. (273 Fed. Rep., 522.)

After a period of experiments the Duryea Co. produced a woven cotton belting which it saturated with a solution of asphaltum and placed upon the market with very favorable results. A patent covering the belting was issued in 1909. In 1917 or 1918 the defendant corporation began to manufacture a similar product and placed it on the market, and plaintiff asked that defendant be enjoined and give an accounting.

The defense was that defendant used the old Pearce & Beardsley patent of 1886, No. 348,993, in the manufacture of its product.

The claim of the Wooster patent is for belting consisting of an absorbent woven fabric body portion which has been saturated with a solution of asphaltum and dried. The old Pearce & Beardsley patent was for a new article of manufacture of all kinds of cloths and fabrics other than for paper and treated with a compound of bisulphide of carbon and maltha substantially as set forth in the patent.

Maltha is described as a soft asphalt, and proof showed that the process of saturating as described by Pearce & Beardsley and the saturation under pressure described by Wooster are substantially the same. The earlier patent describes the process of manufacture with almost the same degree of exactness as that of the plaintiff's patent. True, there had been no general marketing of the product under the first process, but the court said the proof of manufacture under this patent, though slight, indicates a disclosure to the world and made such patent more than a prophetic suggestion, as was urged by plaintiff. Plaintiff's only act beyond the patent of Pearce & Beardsley was the creation of a market for its output, but, says the court, this fact alone, standing by itself, cannot be a ground for sustaining the validity of its patent, which discloses nothing new to the world except the idea of pressure to obtain "saturation," which is obviously only one of a number of means of accomplishing the results.

Contracts of c.i.f. Shipments Construed

In an action by Willets & Patterson against Abekober & Co., Ltd., the plaintiff was a California corporation and defendant was a Japanese corporation. The latter sold the former 750,000 lb. of soya bean oil, payment in full being made for same, but when the oil arrived in San Francisco there was a shortage of 79,555 lb. The purchaser then brought this suit to recover back the proportionate amount of the purchase price paid. (189 N. Y. S., 525.)

Upon an appeal in the case by the plaintiff to the Appellate Division of the New York Supreme Court the sole question presented for determination was whether the plaintiff had shown the existence of the cause of action as set forth in his pleadings, which was an action upon the contract. The trial court held that this contract was simply a c.i.f. contract, and that the perils of the voyage from Japan to San Francisco were at the buyer's risk, and for failure to show that this shortage existed at the time of the delivery to the carrier the plaintiff had failed to show any right of action.

The higher court says the law is well settled that a simple c.i.f. contract requires the seller to deliver to the carrier, and upon such delivery the obligation of the seller is at an end, and the risk is thereafter with the buyer. However, it says these contracts of sale are to be construed according to the intention of the parties to the contract. A straight f.o.b. contract is satisfied by the seller's delivery to the carrier for the purpose of shipment, the risk of transportation resting upon the buyer. If, however, there be anything in the contract which shows that such was not the intention of the parties, the contract will be construed according to their intention.

Intention of the Parties

This same court earlier held, in the case of Standard Casing Co., Inc., vs. California Casing Co. (188 N. Y. S., 358), that in a contract to ship from California to New York, reserving the right of inspection to the buyer at New York, the liability of the seller was shown by this provision to extend to a delivery in New York City, notwithstanding the contract provided for a price f.o.b. San Francisco. In yet another case it was held, notwithstanding a named price f.o.b. at point of shipment, that the right of inspection at the destination of the transportation indicated an intention that the delivery was not to be deemed complete until such destination was reached. Other facts or circumstances may show the intention of the parties.

In the case at bar the sale contract contains the provision "net landed weight." The court construed this to mean the weight at San Francisco must accord with the contract requirements as to weight.

Technical News of the Week

Current Events in the Chemical, Metallurgical and Allied Industrial Fields—Legislative Developments—Activities of Government Bureaus, Technical Societies and Trade Associations

American Electrochemical Society Announces Spring Meeting Plans

A tentative program for the spring meeting of the American Electrochemical Society which is to be held in Baltimore, Md., April 27 to 29, has been announced. Headquarters will be established at the Hotel Emerson. The technical sessions will be held Thursday, Friday and Saturday mornings and will include three symposiums: Electric Furnace Cast Iron, Gases of the Electrochemical Industries and Electromotive Chemistry. By "electromotive chemistry" is meant that branch of electrochemistry which has to do with the production of electromotive forces by means of chemical processes and in a broader sense would include related phenomena as the "photo-electric effect," and allied electronic effects. On the theoretical side, papers on the electrolytic theory of oxidation and reduction, on concentration cells of various types, on potentials at liquid junctions, electrical phenomena in living protoplasm and on the electron theory may be expected. On the industrial side, the practical application of the theoretical aspects of the subject and in particular papers on primary and secondary batteries should provide material for discussion.

The plans under way provide for visits to industrial plants, a complimentary smoker to be given by the chemists and engineers of Baltimore, a golf tournament, a boat trip, an illustrated lecture by Prof. W. R. Wood on "Fluorescence" and an entertainment program for the ladies.

Mysterious Explosion Causes Casualties and Fire at Zapon Plant

The explosion of a tank car supposed to contain mixed acid caused the death of two operators and started a fire which destroyed two of the storage warehouses at the plant of Richards & Co. in Stamford, Conn., on Feb. 24. The Stamford plant is the home of Zapon artificial leather and the lacquer works of Richards & Co.

According to Edward D. Williams, superintendent of the plant, the car of acid, which had been received recently from an acid plant in New Jersey, had been spotted and connected to the line leading to storage tanks. The two operators had phoned to the acid office to have the air turned on the car. Apparently, the explosion occurred just after the air was turned on, although this can never be definitely established. The car sample was destroyed in the explosion so that the analysis of the acid is unknown. Mr. Williams and other plant officials could offer no explanation as to the cause of the accident.

The fire which followed the explosion destroyed two warehouses containing cotton linters, pigments, shipping containers and miscellaneous supplies. Plant officials expect to be operating normally inside of a week.

Patent Office Relief Assured

The President signed the Patent Office relief bill on Feb. 18. Since the bill carries only the authorization for the appropriation, the reorganization and installation of additional personnel must await the actual granting of the money. It is probable, however, that the appropriation can be carried in a forthcoming deficiency bill. The change in patent fees does not become effective until April 19.

Farmers Unite in Protest on Potash Duty

Senator McLean of Connecticut has presented to the Senate a petition of 25,000 New England farmers protesting against a duty on potash.

New Committee Finally Begins Hearings in Long-Delayed Dye Investigation

The initial sessions of the hearing on the Senate resolution calling for investigation of certain activities on the part of domestic dye manufacturers and on the part of importers of foreign-made dyes were devoted largely to a repetition by Senator King of the various charges made by him heretofore in the Senate. He also has covered most of the points made by former Senator Thomas, whose mantle Senator King has assumed. The du Pont Co., the Chemical Foundation and the Textile Alliance were given special attention.

When the committee met for its first hearing, Senator Reed stated that he found it would be impossible to give any time to the investigation. Senator Ernst of Kentucky also was excused from serving. He explained that his law firm is counsel for the Grasselli Chemical Co. and that while he is of the opinion that he could serve without prejudice, he pointed out that the connection was likely to be a source of embarrassment, not only to him but to the sub-committee. This made it necessary for Senator Shortridge of California, the chairman of the sub-committee, to lay the situation before the Judiciary Committee and request the assignment of two of its members to sit with him in the conduct of the investigation. Senator Sterling of South Dakota and Senator Ashurst of Arizona were designated and are sitting with Senator Shortridge.

Frelinghuysen Defends Dye Industries

The delay in getting the investigation started rather nettled Senator Frelinghuysen of New Jersey, who pointed out vigorously that charges are resting over the head of an American industry and that it is entitled to the prompt consideration of its side of the case, if it is not to be handicapped in its contest with the German monopoly which is seeking to dominate the American market. Senator Frelinghuysen demanded, in effect, that Senator Moses of New Hampshire be called upon to prove the charges which he had made against the American dye industry. He promised to lay before the committee evidence as to the activities of the representatives in this country of the German trust and of importers. He said the domestic industry had been built up not only to save the domestic textile industry during the war but to enable the Allies to overcome Germany's initial superiority in chemical warfare. "Germany nearly won," said Senator Frelinghuysen, "by reason of our lack of vision and statesmanship in failing to protect the American dye industry."

The Position of the Textile Alliance

An important statement was made to the committee by F. R. Coudert, attorney for the Textile Alliance. Extracts from his statement follow:

"The Textile Alliance, Inc., is a New York State, non-profit, membership corporation, whose voting members and directors are nominees of trade associations representing practically the entire textile trade of the United States.

"In October, 1919, and several times since the Textile Alliance, Inc., without solicitation on its part, was requested by the Department of State to undertake—and it did undertake—the purchase and distribution of reparation dyes accruing to the United States.

"In October, 1921, a protest was filed with the Department of State against the continuance of this arrangement by Kuttroff, Pickhardt & Co., Inc., a New York corporation, owned and managed by American citizens of German birth, who formerly in their corporate or private capacities were agents of the Badische Anilin- & Soda-Fabrik, one of

the six constituent members of the German dyestuff monopoly. The State Department on Dec. 14, 1921, abrogated the arrangement with the Textile Alliance, Inc., stating that there was no dissatisfaction with the work of the Alliance and that there was no objection by the department to the Reparation Commission continuing the allocation of reparation dyes to American non-profit organizations. Later, letters were given by the department to Kuttroff, Pickhardt & Co., Inc., and to other former representatives of the German dye monopoly, stating that the department had no objection to the Reparation Commission allocating reparation dyes to them.

"As a result the Reparation Commission refuses to continue to supply reparation dyes to America until the Department of State shall decide who the recipients of the American portion shall be.

"If the allocation be divided among profit-seeking corporations connected or formerly connected with the German monopoly, the effect will inevitably be to re-establish the control, not only of reparation dyes but of all German dyes, in the hands of the German monopoly or those representing it.

"The Textile Alliance, Inc., does not seek to continue this work itself and would prefer to have it in the hands of a government department."

Expert Testimony to Be Called

Senator King filed a list of names with the committee asking that each be subpœnaed to appear and to produce books, papers and correspondence and accounts. Among those included in the list are Thomas O. Marvin, chairman of the U. S. Tariff Commission; Julius Klein, director of the Bureau of Foreign and Domestic Commerce; General Amos A. Fries, chief of the Chemical Warfare Service; H. E. Howe, formerly chief of the National Research Council; Charles L. Parsons, secretary of the American Chemical Society; B. R. Price, National Aniline Co.; E. A. Mason and F. L. Fleisch, Textile Alliance, Inc.; Charles H. Herty, president Synthetic Organic Chemical Manufacturers' Association; R. C. Jeffcott, president American Dyes Institute; Samuel Iserman, Chemical Company of America; Irenee du Pont and other representatives of the E. I. du Pont de Nemours & Co. and of the Allied Chemical & Dye Corporation.

Faults in Design, Not Materials, Caused Collapse of R-38

That the accident which wrecked the giant dirigible R-38 at Hull, England, Aug. 21, 1921, was caused by structural weakness in the design of the airship rather than defects in structural material is shown by the report of the Aëronautical Research Committee to the British Air Ministry. The report admits the presence of a certain amount of softened duralumin in the airship, but insists that faulty material did not contribute to the accident. In a summary of its conclusions the committee says that it has reached the following conclusions:

1. That the accident was due to structural weakness in the design of the airship.
2. That during the final flight no loads were imposed in excess of those which might have occurred during the normal navigation of the ship in weather which might reasonably be encountered.
3. That, having regard to her size and speed, R-38 was considerably weaker than R-33.
4. That the provision of specially powerful control surfaces of new design virtually accentuated this weakness.
5. That no calculations were made of the strèsses due to the aërodynamic forces to which the ship would be subjected.
6. That in consequence, the calculations made by the design staff, taking specific account only of the forces and movements due to the distribution of weight and buoyancy, including gas pressures, were misleading.
7. That, owing to instability of the ship, combined apparently with overbalance of the control surfaces, the movements of the controls necessary to keep the ship on any particular course were comparatively larger.
8. That the structure was not improbably weakened by the cumulative effect of reversals of stress of magnitude not far short of the falling stress.
9. That for the progressive development of airships in size and speed reference to first principles in design is necessary, and that it is not sufficient to place exclusive reliance on comparison with existing ships.
10. That the existing methods of calculation at present in use for determining the scantlings of structural members of an airship are insufficiently accurate for this purpose and that more exact methods, the outline of which can at present be indicated, should be developed.
11. That research by both model and full-scale experiment is essential to determine and verify the forces to which an airship is subjected.
12. That the terms of the requirements laid down in time of war for R-38 were extremely drastic and that the limitations involved by the size of the shed in which the airship had to be built imposed too severe a task on the designers.
13. That at the time when the design was originally laid down information as to aërodynamic forces existed which should have led to a more detailed consideration of the effects of these forces and to consultation with the Advisory Committee for Aëronautics as to the dangerous loads foreshadowed by the early model experiments on aërodynamic pressures.
14. That in spite of the presence of a certain amount of softened duralumin in the airship, faulty material did not contribute to the accident.
15. That on the assumption made, the structure was designed with great skill and the necessary calculations were carefully carried out by methods admitted as sufficiently accurate in other branches of engineering practice.
16. That the weather at the time did not contribute to the accident.

The report includes a comparison of R-38 with R-33 from which design data were taken.

Paint Company Operating Novel Pigment-Making Process

The Pacific Color Manufacturing Co., which was organized a year ago to develop the patents of H. D. Swartout, has brought the first unit of its plant at Chilliwack, 70 miles east of Vancouver, B. C., to the producing stage. The process that the company employs for making pigments consists of dissolving galena in dilute nitric acid contained in duro-iron retorts, of special design, heated by steam. The resulting nitrate of lead is drawn off into vats, where the lead is precipitated in different forms by various reagents, giving the desired pigments, while the oxides of nitrogen and any nitric acid that distills over are recovered. The insoluble residue is drawn off from time to time through valves at the bottom of the retorts. The patents cover reagents, temperatures and retort design.

The galena is obtained in the form of concentrate from the Florence Silver Mining Co., which is operating a silver-lead mine at Ainsworth, in West Kootenay. The contract with the mining company calls for a concentrate containing not less than 60 per cent of lead. The first carload delivered contained 67.8 per cent of lead, 8 per cent of iron, and 3 per cent of zinc. The company is using 5 tons of concentrate daily, but expects during the next few months to install another battery of five retorts, which will double its output. The nitrate solution, after the precipitation of the lead salts, will be evaporated and sold for fertilizing purposes.

Soap-Making and Therapeutics Related in Colloid Chemistry

The Lehigh Valley Section of the American Chemical Society was addressed by Martin H. Fischer of Cincinnati at a regular meeting held Feb. 17 at the Hotel Allen, Allentown, Pa. Dr. Fischer chose as his subject, "The Theoretical and Practical Aspects of the Colloid Chemistry of Soaps," his remarks on the application of colloid chemistry to soap making being illustrated by a large exhibit of samples. The speaker also pointed out the relation between the "salting out" of soaps to the neutralization of mercury and lead poisons in the human body by the use of sodium and potassium salts.

Destruction of Dirigible Emphasizes Need for Helium Plants

That no small part of the responsibility for the Roma disaster may be laid at the door of Congress is an opinion very generally held among technical men in Washington. There is unusual frankness on the subject and much space has been given by the newspapers to statements pointing out that helium should have been available for use in this aircraft. The failure of Congress to provide the small appropriations asked was said to be the only reason that sufficient helium was not available. It is pointed out that a valuable natural resource is being allowed to go to waste, although its complete practicability has been proved by the operation of the C-7, which has made upward of fifty trips without any loss of the helium with which it is filled. Representative Lanham, of Texas, has given notice that he will urge that $800,000 be made available at the earliest possible moment for the government's helium plants.

Military Affairs Committee Considers Merits of Muscle Shoals Offers

The most interesting development of the week in the Muscle Shoals negotiations was the transmission to Congress of the offer of the Alabama Power Co., accompanied as it was with the comments of the Secretary of War which emphasized its favorable features.

A detailed statement of the situation with regard to the Gorgas-Warrior plant was made to the committee by J. H. Burns, who until recently was in charge of the Nitrate Division of Ordnance. He explained that the Alabama Power Co. had in operation at the time of the war a 20,000-kw. plant located on the Warrior River. So as to be assured power for the chemical end of the project before power could be made available at Muscle Shoals, a plan was worked out whereby the Alabama Power Co. was to furnish 30,000 kw. provided the government increased the facilities at Gorgas.

"The Alabama Power Co." he said, "agreed to put up this additional plant at cost plus 6 per cent, and definitely agreed that the company would buy back the plant from the government at a specified time at a fair value, to be determined by a board of arbitrators.

"The arrangement was an expedient to get quick power in order to get explosives at No. 2 plant. It seemed to be the very best solution that could be made of the problem at that time. This arrangement with the Alabama Power Co. was a great help to the government in the early days of the war, as it gave us power at the No. 2 plant in May, 1918, a few months after the plant was started and we were never short of power as a result of that connection. Our own steam plant at Muscle Shoals was not accepted finally until long after the armistice.

"Since the time limit provided in the contract has not been reached, no negotiations for the return of the plant have been undertaken. In case the sale is not consummated to the Alabama Power Co., the government must remove its portion of the plant and leave the land in satisfactory condition."

In explaining the difference between the Alabama Power Co.'s contract and that with the Air Nitrates Corporation, Major Burns said: "The American Cyanamid Co. cannot buy Plant No. 2 unless it is willing to make as good a proposition to the United States as the United States is able to get from any other person. It is my judgment that the American Cyanamid Co. would not give the United States as much as Mr. Ford is offering to give. Therefore I feel that the American Cyanamid Co.'s option will not be an impediment."

Ford Bound to Conduct Research

From the beginning of the hearing it has been evident that the committee attached great importance to lack of definiteness in the Ford offer in the matter of fertilizer manufacture. Even the Secretary of Agriculture qualified his approval of the Ford proposal by specifying that its terms must be found binding so that the plant will be operated continuously for the manufacture of fertilizer. In an effort to meet this objection, Mr. Ford has agreed to alter the contract so as to give a definite guarantee to produce a complete fertilizer at a given minimum annual tonnage. In his testimony before the committee, W. B. Mayo, chief engineer of the Ford Motor Co., made it very clear that it had been Mr. Ford's intention from the first to produce a complete fertilizer. It was his idea, however, that the contract should not make it binding to produce fertilizers at a loss. He agreed that Mr. Ford's company is bound by the proposal to conduct experiments and research work throughout the 100 years. "The only valid reason for discontinuing," said Mr. Mayo, "would be that it had been proved by every possible effort to be an absolute impossibility to make the product there with a profit."

Fertilizer Interests Point Out Existence of Surplus of Ammonium Sulphate

C. H. MacDowell, president of the National Fertilizer Association, in his recent testimony declared that there is no necessity for the manufacture of nitrate for agricultural purposes. He said that coke ovens and city gas works have a capacity of 550,000 tons of sulphate of ammonia annually and that after the fertilizer and other domestic demands are met there still would be an exportable surplus of about 150,000 tons.

The need for maintaining Nitrate Plant No. 2 in readiness for an emergency was emphasized by Mr. MacDowell, who was in charge of the chemical division of the War Industries Board for a time during the war. At that time the country was mainly dependent on Chile for its nitrogen. Stocks fell so low at one time during the war that they were sufficient only for 4 weeks requirements. As a result of that grave experience, he said, there is every reason why the plant should be retained in standby condition ready for operation.

Surplus of Ammonium Sulphate Only Temporary, Says Whitney

Particular significance was attached to the testimony of Milton Whitney, chief of the Bureau of Soils, in view of the fact that some of the arguments made before the committee have been based on the existing price of ammonium sulphate. The inference drawn from Dr. Whitney's remarks by some members of the committee is that decided increases in prices may be expected as the use of fertilizer returns to the normal rate.

"We have an overabundant supply just now of nitrogen in all of its forms," said Dr. Whitney, "because the farmers did not purchase last year. Under normal conditions we have been keeping up with the demand for fertilizers, but there has been an impossibility of getting nitrogenous material in sufficient amount for any great expansion in their use. I have had this matter up with the fertilizer manufacturers. If they were to be successful in getting a demand for 2,000,000 tons of fertilizers in the wheat and corn states, we then could not get the nitrogen to supply it.

"With the demand for fertilizers increasing 7½ per cent per annum, it is becoming more and more difficult to get adequate supplies of ammonia. We have plenty of phosphoric acid and we are searching very diligently for potash; anyway we can get it from the European sources. Nitrogen is the limiting factor. If we have the fixed nitrogen products, we must change our fertilizer system in order to use them to the best advantage."

Fertilizer Investigation Proposed on Charges of Muscle Shoals Lobbying

A resolution to investigate an alleged fertilizer trust which is said to be lobbying against acceptance of the Ford offer to lease the Muscle Shoals plant was introduced in the Senate by Senator McKellar of Tennessee on Feb. 17. The proposed investigation would be conducted by the Senate Agriculture Committee to determine whether there is a fertilizer trust, whether the industry is controlled by a combination of corporations and whether it has employed lobbyists to influence Congress against accepting the Ford offer.

Industrial Developments of the Week

Glass. — The American Window Glass Co. has resumed operations at its plant at James City, near Kane, Pa., following a shut-down since early in December.

The B-R-C Bottle Co., Cedar Grove, La., has resumed operations at its plant after a period of curtailment. Employment will be given to about 200 men.

The Owens Bottle Co., South Glassboro, N. J., is operating its bottle-blowing plant at full capacity, with three-shift working forces.

Paper. — The American Writing Paper Co., Holyoke, Mass., has resumed production at its local Gill division plant, following a period of curtailment. Operations will be on a basis of 60 tons of paper per day.

The J. C. Blair Co., Huntingdon, Pa., manufacturer of paper specialties, has advanced production to a full-time schedule of 54 hours a week. The plant has been running on a short-time basis since last year.

Leather.—The E. C. Mills Leather Co., Middleville, N. Y., is operating at a capacity schedule at its tannery.

Tarlow Bros., Brockton, Mass., are maintaining operations on a full capacity schedule.

McAdoo & Allen, Philadelphia, Pa., are increasing production at their welting plant at Quakertown, Pa. and are arranging for early expansion, providing additional floor space and increased working force.

Refractory.—The National Fire Brick Co., New Philadelphia, Ohio, has resumed production at its local plant, following several weeks idleness.

Iron and Steel.—The Pittsburgh Steel Co., Pittsburgh, Pa., has resumed operations at six furnaces at its open-hearth plant.

The Berwick Rolling Mills, Berwick, Pa., have reopened the finishing department at their local plant, following a period of curtailment, and will give employment to about 200 additional men.

The Hanna Furnace Co., Cleveland, Ohio, is making repairs at its furnace at Dover, Ohio, and placing the unit in readiness for blowing in. It has been closed down since December, 1920.

The Carnegie Steel Co., Pittsburgh, Pa., is operating two of its Lucy furnaces full, for the production of ferromanganese and spiegeleisen.

The Follansbee Bros. Co., Pittsburgh, Pa., is operating on a full time schedule at its steel mills at Follansbee, W. Va., recently reopened.

The Illinois Steel Co., Chicago, Ill., has placed another furnace in blast at its Gary, Ind., works, making a total of eleven stacks now active, comprising six at Gary, four at the South Chicago works and one at Joliet, Ill.

The Jones & Laughlin Steel Co., Pittsburgh, Pa., has seven blast furnaces operating full for the production of iron. It is planned to place another furnace in blast at the Woodlawn works for the production of ferromanganese at an early date.

The Inland Steel Co., Chicago, Ill., has adopted a capacity schedule in its sheet department. The structural mill, continuous mill and nine open-hearth furnaces are also active. It is proposed to resume operations at the plate mill at an early date.

Metals.—The El Paso Smelting Works, El Paso, Tex., is making ready to resume operations at five of its lead furnaces, which will be more than have been in service for a number of years past. The company is also planning for early resumption of operations in the copper furnace department.

The Nevada Consolidated Copper Co., Ely, Nev., has arranged for the immediate resumption of production at its local smelters on a 60 per cent basis. The mines, also, will be reopened.

The Anaconda Copper Co. is increasing production at its Great Falls, Mont., electrolytic plant from 2,000,000 to 4,000,000 lb. of copper per month. This will be increased to a maximum of 7,000,000 lb. as soon as sufficient concentrates from the mines are available.

Powder.—E. I. du Pont de Nemours & Co. are giving employment to about 500 operatives at their Carneys Point, N. J., plant, under full-time operation.

Connecticut Valley Section, A.C.S.

The Department of Chemistry of Smith College was host to the Connecticut Valley Section of the American Chemical Society on Feb. 4, 1922. The members were given opportunity to inspect the college laboratories and to visit the mills of the McCallum Hosiery Co., the Nonotuck Silk Co. and the Florence Manufacturing Co.

The speaker of the day was W. T. Bovie of Harvard University, who addressed the section on "The Structure of Protoplasm."

Personal

HARRY BREARLEY, works manager of Brown Bayley's Steel Works, Sheffield, England, and well known for his writings on steel metallurgy, is in the United States for a brief stay.

J. A. CULLEN has been assigned to cement experiment work at the Columbus Station of the U. S. Bureau of Mines.

H. A. DOERNER has been assigned to rare-metal work at the Reno experiment station of the Bureau of Mines. Mr. Doerner was formerly connected with the Denver office of the Bureau of Mines. For several years past he has been engaged in commercial work.

F. B. FOLEY, metallurgist, Minneapolis Station of the Bureau of Mines, has been in Washington recently. He presented a discussion of "The Annealing and Hardening of Steel" before the Washington Chapter of the American Society for Steel Treating at its monthly meeting Feb. 17.

J. J. FORBES, coal-mining engineer of the Bureau of Mines, is collecting data for the preparation of a bulletin on sampling and analysis of Alabama coals. This bulletin will give information regarding the coals of the Birmingham district. One hundred and forty-nine face samples of coal have been taken in thirty-four mines in Alabama, representing fourteen different coal beds.

A. P. GEST, JR., formerly assistant superintendent of the Frankford Plant of The Barrett Co. and more recently in the technical service department as expert on the industrial uses of coal-tar solvents, is now associated with Keator & Wilson, Philadelphia, Pa., as Eastern representative of the St. Louis Pump & Equipment Co., St. Louis, Mo., and of Morrison Bros., Dubuque, Iowa.

C. F. GRASS, president and general manager of the American Nitrogen Products Co., Seattle, Wash. was in New York last week.

H. W. HARDINGE, of Hardinge Co., New York, sailed Feb. 15 on the S. S. *Baltic* for Europe, and plans to return about the middle of April.

HAROLD E. MARTIN, who last May left the General Chemical Co., where he was employed as an engineer in the research department, is now with Johns-Manville, Inc., in the New York insulation and power plant specialties department.

Dr. DUNCAN MACRAE, physical chemist for the Westinghouse Lamp Co., delivered a lecture on "Physical Chemistry and Some of Its Applications" before the senior class in chemistry of the Cooper Union night school on Feb. 23.

Dr. C. E. KENNETH MEES, director of research and development, Eastman Kodak Co., gave several lectures in Montreal and Toronto during the last week of February. On Feb. 20 at Montreal he spoke before the Canadian Club on "The Road to Wealth." The same evening he lectured before the Montreal Section of the Society of Chemical Industry on "Chemistry and the Motion Picture." At Toronto he gave the following lectures: Feb. 21, "Photography Through the Microscope," before the Camera Club; Feb. 22, "Chemistry and the Motion Picture," before the Toronto Section of the Society of Chemical Industry; Feb. 23, "The Getting of Wisdom" before the Empire Club, and "A Hundred Years Hence," before the Canada First League.

Dr. CLARK MINTER, of the Hanovia Chemical Co., delivered a lecture on "Osmotic Pressure" before the senior class in chemistry of the Cooper Union night school on Feb. 9.

Market Conditions

IN CHEMICAL, METALLURGICAL AND ALLIED INDUSTRIES

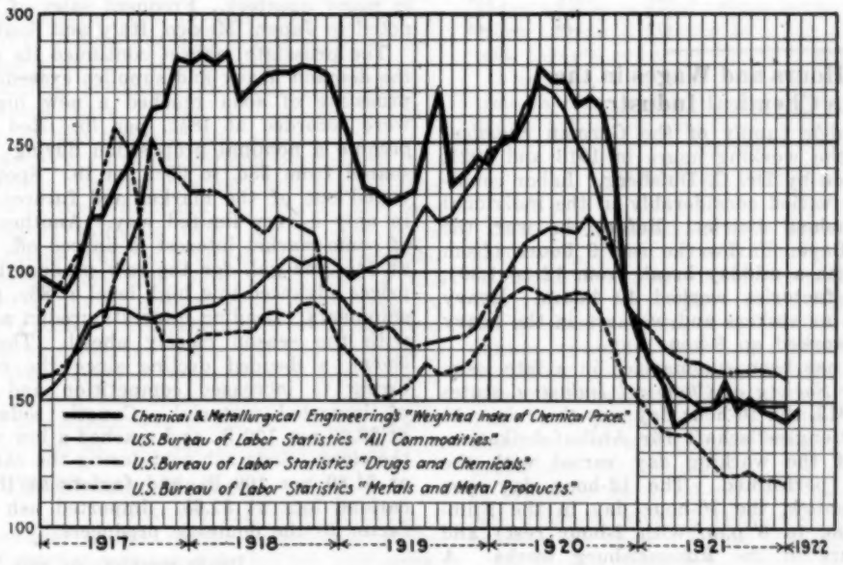
A Survey of the Economic and Commercial Factors That Influence Trade in Chemicals and Related Commodities—Prevailing Prices and Market Letters From Principal Industrial Centers

Fundamental Progress in Business During February

Underlying conditions improved somewhat during February, but the progress toward better business has been slow and painful. The general upward trend of business has been punctuated with reactions, many of which had depressing effects on industry.

Outstanding among the developments of the month have been the threatened coal strike with its almost inevitable consequences to industry, the serious agitation for the soldier bonus with its menace to business progress, and the continued wage disputes, which have added greatly to the ranks of the unemployed. On the other side of February's ledger are to be noted the striking rise in foreign exchange, the noticeable upturn in certain commodity prices, and finally the announcement of the government's more sympathetic attitude toward industry as evidenced by Secretary Hoover's defense of the trade association and other methods of modern business.

The proposed miners' strike, directly involving soft- and hard-coal miners in more than twenty states, may have a most serious effect on industry if we are to judge from the disastrous results of the late British coal strike. Even today Great Britain's foreign trade is suffering from ailments which economists declare are directly attributable to that long tie-up of industry. As is doubtlessly well known, all wage agreements in American coal mines will terminate April 1 and unless the miners force the acceptance of a new and higher wage scale, production will cease. The effects will be felt most seriously by industry, for supplies are adequate to meet the householders' demands, especially since in most sections, the weather will have moderated considerably by April 1. Those most familiar with the situation are confident that, whatever the temporary consequence, the net result will be a downward turn in the present inflated prices of coal. Still 90 per cent above pre-war levels, lower coal prices are generally regarded as inevitable.



A COMPARISON OF WHOLESALE PRICES, 1917-1922

CHEMICAL & METALLURGICAL ENGINEERING'S WEIGHTED INDEX OF CHEMICAL PRICES

Base = 100 for the year July 1, 1913, to June 30, 1914

This week	151.21
Last week	149.05
March, 1921	157
March, 1920	252
April, 1918 (high)	286
April, 1921 (low)	140

This index number is based on the wholesale prices in the New York market for acetic acid, citric acid, hydrochloric acid, nitric acid, sulphuric acid, ethyl alcohol, methanol, anhydrous ammonia, ammonium sulphate, barium chloride, bleaching powder, borax, caustic potash, caustic soda, copper sulphate, formaldehyde, glycerine, potassium carbonate, saltcake, soda ash, crude sulphur, benzene, aniline oil, cottonseed oil and linseed oil.

The sensational financial development of the past month has been the sharp rise in sterling and the sympathetic strengthening of practically all of the other exchanges. After averaging $4.16 for December and $4.22 for January, the British pound opened the past month at $4.28, crossed $4.37 on Feb. 9, and then after a temporary slump, jumped to $4.41 7/8 on Feb. 23. This is the highest level reached since 1919. The exchange on Paris has risen from $0.0835 on Feb. 1 to $0.0913 on Feb. 24 and the Italian lire from $0.0466 to $0.0502. The business situation in Great Britain is not generally regarded as sufficient in itself to have so strengthened the exchange. The most likely explanation is that it is the cumulative effect of smaller imports, the apparent arrangements to provide £25,000,000 to cover 6 months interest on the English debt to the United States, and finally the larger exports of gold. Announcement was made on Feb. 20, that in the one week ended Jan. 18 Great Britain had exported £1,276,816 in gold to the U. S.

On Feb. 3 wages in the textile mills of the three states of Massachusetts, New Hampshire and Maine were greatly reduced. Other states immediately followed suit. This cut of 20 per cent, following a general reduction of 22½ per cent which was put into effect early in January, 1921, has resulted in a strike of very generous proportions. The chemical industry is not so organized as to be affected by such blanket wage decreases, but during the past month more than one prominent dyestuff and chemical manufacturer has made drastic reductions both in salaries and personnel. Reducing wages is the most obvious path to lower costs, but it is also the most difficult.

Wholesale Prices

Although the general level of prices has probably remained almost stationary, a number of important commodities have shown an upward tendency during February. Particularly is this true in the chemical market. CHEMICAL & METALLURGICAL ENGINEERING'S Weighted Index of Chemical Prices stood at 144.60 on Feb. 1, increased to 147.33 on Feb. 8, to 149.05 on Feb. 22 and on March 1 had risen to 151.21. This is highest level of chemical prices

since October, 1921. These higher prices are not necessarily to be regarded, however, as progress toward business recovery in the chemical industry. They may mean speculation and artificial activity, but as has often been pointed out in these columns, the essential requirement is the proper adjustment between the great groups of commodity prices and between such economic factors as costs, wages and transportation.

Wholesale Prices in January

The U. S. Bureau of Labor Statistics index numbers indicate that wholesale prices in general averaged somewhat lower in December than in the preceding month. The bureau's "all commodities" index number, comprising 327 price series, stood at 148 for January, compared with 177 for January, 1921.

Below are shown the index numbers of wholesale prices in the United States, by groups of commodities, as computed by the Bureau of Labor Statistics for the months named.

INDEX NUMBERS OF WHOLESALE PRICES, BY GROUPS OF COMMODITIES. (1913 = 100)

	1921		1922
	January	December	January
Farm products	136	113	116
Food	162	139	134
Cloths and clothing	208	185	183
Fuel and lighting	228	187	183
Metals and metal products	152	119	117
Building materials	239	203	202
Chemicals and drugs	182	161	159
House furnishing goods	283	218	214
Miscellaneous	190	148	146
All commodities	177	149	148

Working Hours and Wages in the German Chemical Industry

A report on the labor supply of the German chemical industry, comparing the working hours in 1913 and 1921, has recently been made by Dr. C. Duisberg. Labor conditions have apparently varied considerably in the individual factories of the Rhineland district. Before the war, the working day at the Bayer Farbwerke was 9 hours (from 7.30 a.m. to 6 p.m. with a midday break from 12 to 1.30), but as a rule most factories worked 10 hours. Heavy manual laborers, such as stokers and workers in the heavy chemical industries, worked an 8-hour day.

This report, which has been summarized in a late issue of the *Journal of the Society of Chemical Industry*, states that at Hoechst, in 1913, the 10-hour day was the rule. At the works of the Aktiengesellschaft für Anilinfabrikation, Berlin, the length of the working day varied with the nature of the work performed. The 12-hour day was worked at Berlin-Treptow, the 10-hour day in the Filmfabrik Wolfen (6 a.m. to 6 p.m. with 2-hour rest) and either 11 or 13 hours in the Rummelsburg works. A special working day of 8½ hours for women was provided in one of the plants.

At the Badische Anilin- und Soda-Fabrik at Ludwigshaven, labor conditions were said to resemble those at the Leverkusen plant of the Bayer company. The 9-hour day (7.30 a.m. to 12 m. and 1.30 p.m. to 6 p.m.) was the usual basis, although the pay was for 10 hours. In some instances where there was need for continuous service the men worked in 12-hour shifts from 6 to 6 and were paid for 13 hours.

Directly after the revolution in November, 1918, the 8-hour day was introduced into the chemical industry. Among the rules set down by the German *Reichsanzeiger* were the following:

"The working time, including rest periods, shall be 8 hours.

"By agreement, the working hours on Saturday may be shortened, the time lost being spread over other days.

"Female workers over 16 years may be employed, where two or more shifts are worked, up till 10 p.m., provided they are then allowed a rest period of at least 16 hours."

These rules are said to have been universally accepted in the chemical industries. The 8-hour day, with a half hour break from 12 to 12.30 p.m. is most common. Where shifts are worked they commence at 5.55 a.m., 1.55 p.m. and 9.55 p.m. and end at 2.05 p.m, 10.05 p. m. and 6.05 a.m. respectively.

The New York Market During February

NEW YORK, Feb. 27, 1922.

The chemical market during the past month showed very little signs of recovery. On the surface, the total amount of business for February seems to have increased over the preceding month. However, the persistent conservatism on the part of buyers to limit their purchases to immediate requirements, together with the policy of large manufacturers to hold production at a minimum, has had a disastrous effect on the general trend of trading and has retarded any forward movement. The steady arrivals of imported materials at extremely low figures has also been a severe handicap and has caused serious consideration among many of the largest domestic producers.

During a recent address before the Rochester Section of the American Chemical Society, Dr. W. J. Hale of the Dow Chemical Co. stated that his company is selling at 12c. per lb. bromide which is actually costing 23½c. per lb. to produce and is doing this in order to prevent the Germans from dumping on the American market vast quantities of the product now held in Eastern warehouses.

One of the encouraging developments of the month was the advance in foreign exchange, and this has been reflected in the export market in the form of expansion in trading and has also served as a limited bar on imported materials. Foreign buying during the past few weeks has been practically the only hopeful sign in the industry and an appreciable increase has been reported in many quarters. Frequent sales of large tonnages were noted to Japan, Mexico, Italy and South America.

The prussiate market continued its steady advance, with the demand heavy and supplies exceedingly scarce. Yellow prussiate of soda reached a new high level when sales were recorded at 18½c. per lb. Red prussiate of potash became a nominal proposition during the month as prices soared from 33c. to 60c. per lb. Spot supplies have been wiped out of the market and futures have been reported in only a very limited way. Another item that has been of some market interest is linseed oil. Opening the month at 74c. per gal. for the raw product in carload quantities, prices advanced to a high level of 86c. per gal. for February shipments. Leading interests predict a much higher market with the season closely ahead. The alkali market has shown a decided decline since the opening of February owing to increased competition and large spot supplies of imported material. Caustic soda opened the month at $3.60 per 100 lb. and reached a low mark of $3.25 toward the close. Soda ash sold during the early part of the month at $1.80 per 100 lb. and factors at the close were selling carload lots at $1.65. Imported ash has been a serious factor to the domestic producers.

DEVELOPMENTS OF THE WEEK

Trading, in general, has uncovered no striking developments during the past week. Small lots still continue to rule the market, although a few inquiries were noted for round quantities at a fraction under quoted figures. There were rumors in the trade that imported nitrite of soda was slated for a sharp advance and holders began to tighten offerings with the memory of the March, 1920, movement that resulted in increasing the price to 60c. per lb. Domestic producers have already advanced prices a full cent per lb., making the market 8½c. per lb. at the works. Oxalic acid was reduced by leading interests to 12c. per lb. This is the lowest first-hand price since last November. Competition was responsible for a reduction in formaldehyde at the works. Caustic soda has merited added attention for export and considerable small-lot business has been placed at slightly higher figures. Prussiate of soda touched a new high mark of 8½c. per lb. This is the highest price paid since November, 1920.

THE COMMODITY MARKETS

Alums—Ammonia alum held by domestic producers was quoted on a basis of 3½@3¾c. per lb. for the lump. Imported potash alum is quoted freely at 3¼@3½c. per lb.

Barium Chloride—Sales were recorded during the week at slightly lower figures—around $55 per ton on spot.

The market was very firm at the figure toward the end of the week, with some interests asking up to $57 per ton.

Bicarbonate of Soda—Producers' quotations remain unaltered at 2c. per lb. for barrels f.o.b. works. Spot material, however, is on the market as low as $2.10 per 100 lb. Some small lot sales were made at $2.15.

Caustic Potash—There was an appreciable improvement noted in the consuming inquiry for the imported. The 88-92 per cent is quoted at $5.65@$5.75 per 100 lb., with shipment goods held at $5.60@$5.85 c.i.f. Domestic producers are still asking 8c. per lb, f.o.b. works.

Caustic Soda—Leading factors stated that February shipments have been heavily sold and the market looks much firmer. March shipments are quoted at $3.35@$3.40 per 100 lb. f.a.s. and April at $3.30, although the latter can possibly be purchased on a firm bid of $3.25. Export inquiries are holding up fairly well.

Citric Acid—The consuming inquiry has not shown any appreciable increase, but the tone of the market is much stronger, owing to the advice from abroad indicating a restricted output. Some of the largest producers in Italy were reported to be closed down. Spot goods are quoted at 45c. per lb.

Formaldehyde—The domestic as well as the export demand continues quiet and the market has shown the effect of the competition for new business. Producers quote from 9@10c. per lb., f.o.b. works, in barrels.

Nitrite of Soda — A distinctly firmer market has been brought about with the exhaustion of spot foreign supplies and some domestic factors have advanced their prices to 8¼c. per lb. at works. There are only a few scattered lots available on the open market at this figure.

Oxalic Acid—Leading producers reduced prices sharply at the works. Goods were offered at 12c. per lb. and upward, depending on the quantity and seller.

Prussiate of Soda—Very firm conditions continue to prevail for spot material. Limited offerings and a good consuming inquiry have been sufficient to create this condition. Dealers report sales at 18¼c. per lb. and it is doubtful if better prices could be obtained in any direction.

Shellac—The market has been very active during the past week and prices moved upward from 5@7c. per lb. on practically all grades. Arrivals at New York were reported larger, but as a market factor this was completely overshadowed by the receipt of news that a large cargo of shellac from Calcutta has been wholly or partly destroyed by fire. The demand was active for nearby material. T. N. was quoted at 73c. per lb., superfine at 77c.

The Chicago Market

CHICAGO, ILL., Feb. 23, 1922.

A slight improvement of the general conditions in the industrial chemical market was noted during the past week. Sales have increased and the inquiry is more active. Buying continues to be for small or moderate quantities but the volume of this business is reported as very satisfactory. Prices as a rule are unchanged and the tendency with a few exceptions is upward. This upward trend is to be noticed particularly on chemicals of foreign origin as cable quotations from abroad were sharply higher.

GENERAL CHEMICALS

Contract business for alkalis is reported as brisk and small sales from warehouse stocks as dull. Prices are slightly weaker in some directions, which is probably due to the necessity of moving present stocks. Small lots of solid *caustic soda*, 76 per cent, were quoted at $3.75 per 100 lb. delivered to the consumer. *Soda ash* on spot was rather quiet with $2.30 per 100 lb. for 58 per cent material in cooperage the prevailing offer. *Caustic potash* was firm at 6¼c. per lb. for 88-92 per cent material.

Ammonium chloride is unchanged as to price and is reported to be moving fairly well at 7¾c. per lb. for the white granular in casks. *Ammonium carbonate* is rather quiet and small lots on spot are offered at 9@10c. per lb. *Bleaching powder* is firm at 3c. per lb. delivered and is said to be moving in a fair way. *Copper sulphate*, like the metal, is very firm and 6c. was the prevailing quotation, although it was still possible to do $5.90 per 100 lb. in one direction. While *formaldehyde* was reported to be moving well, prices were a little weak and 10c. per lb. could very likely have been shaded for a fair-sized lot. *Glycerine* was in fair demand and unchanged at 16¼c. per lb. for c.p. material in drums. *Epsom salts* are in but small demand with plentiful supplies of U.S.P. material available at 2¾c. per lb.

Bichromates are enjoying a fair demand and supplies are reported to be not very heavy. *Potash bichromate* is quoted in single-cask lots at 11¾c. per lb. and the soda at 9@9¼c. *Yellow prussiate of potash* is in brisk demand and with supplies light, prices are firm at 27@28c. per lb. The market is entirely clear of the *red prussiate* and even a firm offer for future delivery could not be had. Cables abroad also failed to locate any material for prompt shipment. Several large sales of *sodium bicarbonate* were reported, but aside from these only a few small lots changed hands. Spot material in cooperage is available at $2.35 per 100 lb. *Hypo* is very quiet, with only small parcels moving. Prices remain the same, $3.95 per 100 lb. for pea crystals in barrels. *Silicate of soda* appears to be moving in a fair way and single drums of the 40 deg. material is quoted at $1.40 per 100 lb., drum extra.

Linseed Oil — The movement of linseed oil continues slow, buyers showing a pronounced reluctance to take on even small supplies at the present high level. Boiled oil in single drum lots was offered today at 88c. per gal., drum extra, and similar lots of the raw at 86c.

Naval Stores—Turpentine is slightly lower in price but the movement continues slow. Single drums were quoted today at 95c. per gal., drum extra, delivered to the buyer's store. Rosin is moving in a fair way and $8.50 per 280 lb. was today's prices of the WW grade in less than carlots.

Furfural—Technical furfural was available for the first time in commercial quantities, the offer being 50c. per lb., drums extra, for quantities larger than 100 lb.

The Iron and Steel Market

PITTSBURGH, Feb. 24, 1922.

Steel mill operations have increased a trifle more in the past week, reflecting still heavier buying, since practically all production is against orders placed for prompt shipment. The rate of steel ingot production in the past fortnight has probably averaged 27,000,000 or 28,000,000 tons per annum, against a rate under 18,000,000 tons at the end of December and a rate of 23,000,000 tons in October and November, denoting the volume of last autumn's demand. Thus with spring not yet arrived the demand rises well above that of last autumn. When eventually the curve of production can be plotted, this spring's demand is likely to represent 25 or 30 per cent more demand than that of last autumn, while a reasonable expectation is that next autumn will show a higher tide still.

Up to date there is no indication that buyers will depart from their practice of buying steel practically from hand to mouth. The old practice of distributers and manufacturing consumers carrying large stocks of steel, and of various interests carrying large stocks of manufactured wares, seems to be abandoned for quite a period. A necessary consequence would be that of demand upon the steel mills exhibiting much greater seasonal variations than has ever been the case before. Part of the ups and downs in steel demand has been due to buyers accumulating stocks at one time and liquidating at another time, these movements having no particular connection with the calendar.

There is lacking any comprehensive method of determining what the consumptive requirements or capacity of the country really are. When it is known, for instance, that steel ingots are being produced at the rate of, say, 28,000,000 tons per annum, there is no standard with which to compare this number of tons except the productive capacity, and that obviously is not a standard equally applicable to consumption. The happy state of productive capability and consumptive capability being balanced is unlikely to obtain in any commodity. That is one reason why the practice much in vogue in the past of indicating the rate of steel production by expressing it in terms of percentage of productive capacity is avoided in these reports. Such statements are both misleading and depressing. The

capacity has been estimated for some time past at about half way between 50,000,000 and 55,000,000 tons, in steel ingots.

A Broad Demand

The breadth of steel demand is the most conspicuous feature of the market. The agricultural implement trade is conspicuous for its almost complete absence, while practically every other steel-consuming industry is buying in a fair way. The electrical industry is buying much more freely than 2 or 3 weeks ago. Material required in dwelling house construction is doing very well, illustrated by there being a demand not far from normal for standard steel pipe, while the sheet mills are receiving larger orders from makers of eave trough and conductor pipe, metal lathing and ceiling, etc. Although out of season, the petroleum industry is buying in a very moderate way. The automobile trade is taking fair tonnages and is buying steadily instead of for extended deliveries. Railroad buying is somewhat more in evidence.

All appearance that buyers of steel are waiting for something to turn up is a thing of the past. Business is being conducted, and buyers are ordering freely. They do not buy for extended delivery and perhaps will not do so for a long time to come. A distinct possibility, however, is that of mills falling somewhat behind in deliveries whereby buyers would be forced to stock up in a moderate way instead of depending on mills for almost instant shipment against mixed specifications. This would create an extra tonnage demand for a time, the more important feature from the mill standpoint being that it would permit of better and more economical scheduling of rollings.

Steel Prices

With the gradual sagging in prices of bars, shapes and plates already reported, whereby 1.40c. became the more common market price, there is a tendency for this price to be adhered to with considerable strictness. It is possible that the market may be what is called "stabilized" at this figure, with the possibility of some contracting at this price, to be followed by a slight advance to "protect the contracts" in accordance with a principle the mills frequently invoked before the war. Certainly there is no room, with wages and freight rates as they stand, for the general market to go an appreciable amount lower.

In sheets the prices ruling for about 3 months past, 2.25c. on blue annealed, 3c. on black and 4c. on galvanized, are well maintained. Separate testimony to that fact is afforded in the American Sheet & Tin Plate Co. opening its order books, Feb. 20, for second quarter business at these figures. On the heavy gages, say 12 gage and under, there is plate mill competition.

Wire nails, which have been $2.40@$2.50 for several weeks, depending on size of order, show the $2.40 price more and more frequently. In standard steel pipe the extra concession of 2½ per cent, commonly given by independents, has lately been more often 5 per cent, and at present a total of 7½ per cent is sometimes found.

Pig Iron

Basic pig iron presents rather a complicated market. The furnaces insist that they are firm at $18 valley as minimum, with an asking price of $18.25, but a recent purchase reported to have been at $18 valley is believed in some quarters to have been of resale iron, from a middle interest, at $17.65. Foundry iron has been bought from a valley furnace in one case at $18.75, though some sales have also occurred at the old minimum of $19. Bessemer is down 50c., being quotable at $20.96 delivered Pittsburgh or $19 valley, the occasion being a sale of a few hundred tons by the Cambria Steel Co., which recently decided to devote part of its furnace capacity to the production of merchant iron. Freight to Pittsburgh is the same from Johnstown as from the valleys, $1.96.

Connellsville coke maintains the advance reported a week ago, but has not advanced farther, spot and prompt being quotable at $3.25@$3.50 for furnace and at $4@$4.25 for foundry per net ton at ovens.

General Chemicals

CURRENT WHOLESALE PRICES IN NEW YORK MARKET

		Carlots	Less Carlots
Acetic anhydride	lb.	—	$0.40 – $0.42
Acetone	lb.	$0.12½ – $0.12½	.13 – .13½
Acid, acetic, 28 per cent.	100 lbs.	2.50 – 2.60	2.65 – 3.00
Acetic, 56 per cent.	100 lbs.	5.00 – 5.25	5.30 – 5.50
Acetic, glacial, 99½ per cent, carboys, 100 lbs.		9.00 – 9.50	9.75 – 10.00
Boric, crystals	lb.	.11½ – .11½	.12 – .13
Boric, powder	lb.	.11½ – .12	.12½ – .13
Citric	lb.	—	.45 – .45½
Hydrochloric	100 lb.	1.15 – 1.25	1.30 – 1.75
Hydrofluoric, 52 per cent.	lb.	.11 – .11½	.11½ – .12
Lactic, 44 per cent tech.	lb.	.09½ – .10	.10½ – .12
Lactic, 22 per cent tech	lb.	.04 – .04½	.04½ – .05
Molybdic, c.p.	lb.	3.00 – 3.25	3.30 – 3.75
Muriatic, 20 deg. (see hydrochloric)		—	—
Nitric, 40 deg.	lb.	.06½ – .06½	.06½ – .07
Nitric, 42 deg.	lb.	.06½ – .07	.07½ – .07½
Oxalic, crystals	lb.	.12 – .12½	.13 – .14
Phosphoric, 50 per cent solution	lb.	.08 – .08½	.08½ – .09½
Picric	lb.	.20 – .25	.27 – .35
Pyrogallic, resublimed	lb.	—	1.65 – 1.75
Sulphuric, 60 deg., tank cars	ton	10.00 – 11.00	..... – .....
Sulphuric, 60 deg., drums	ton	12.00 – 14.00	..... – .....
Sulphuric, 66 deg., tank cars	ton	16.00 – 16.50	—
Sulphuric, 66 deg., drums	ton	20.00 – 20.50	21.00 – 22.00
Sulphuric, 66 deg., carboys	ton	..... –	..... – .....
Sulphuric, fuming, 20 per cent (oleum) tank cars	ton	19.50 – 20.00	..... – .....
Sulphuric, fuming, 20 per cent (oleum) drums	ton	22.00 – 22.50	23.00 – 24.00
Sulphuric, fuming, 20 per cent (oleum) carboys	ton	31.00 – 32.00	33.00 – 34.00
Tannic, U. S. P.	lb.	..... –	.60 – .75
Tannic (tech.)	lb.	.40 – .45	.46 – .50
Tartaric, imported crystals	lb.	..... –	.25 – .26
Tartaric acid, imported, powdered	lb.	..... –	.26 – .29
Tartaric acid, domestic	lb.	..... –	— .30
Tungstic, per lb. of WO	lb.	..... –	1.00 – 1.10
Alcohol, ethyl	gal.	..... –	4.75 – 5.50
Alcohol, methyl (see methanol)		..... –	..... – .....
Alcohol, denatured, 188 proof No. 1	gal.	..... –	.36 – .37
Alcohol, denatured, 188 proof No. 5	gal.	..... –	.36 – .37
Alum, ammonia, lump	lb.	.03½ – .03½	.04 – .04½
Alum, potash, lump	lb.	.03½ – .03½	.03½ – .05
Alum, chrome lump	lb.	.07½ – .08	.08½ – .08½
Aluminum sulphate, commercial	100 lb.	1.65 – 1.85	1.90 – 2.40
Aluminum sulphate, iron free	lb.	.02½ – .02½	.03 – .03½
Aqua ammonia, 26 deg., drums (750 lb.)	lb.	.07½ – .07½	.08 – .08½
Ammonia, anhydrous, cyl. (100-150 lb.)	lb.	.30 – .30½	.31 – .33
Ammonium carbonate, powder	lb.	.07 – .07½	.08 – .09
Ammonium nitrate	lb.	.06½ – .07	.07½ – .07½
Amylacetate tech.	gal.	—	2.00 – 2.40
Arsenic, white, powdered	lb.	.07 – .07½	.07½ – .08
Arsenic, red, powdered	lb.	.12 – .12½	.12½ – .13
Barium chloride	ton	55.00 – 57.00	58.00 – 70.00
Barium dioxide (peroxide)	lb.	.21 – .21½	.22 – .23
Barium nitrate	lb.	.06½ – .07	.07½ – .08½
Barium sulphate (precip.) (blanc fixe)	lb.	.03½ – .04	.04½ – .04½
Blanc fixe, dry	lb.	.04 – .04½	..... – .....
Blanc fixe, pulp	ton	45.00 – 55.00	—
Bleaching powder	100 lb.	2.00 – 2.25	2.30 – 3.25
Blue vitriol (see copper sulphate)		—	—
Borax	lb.	.05½ – .05½	.06 – .06½
Brimstone (see sulphur, roll)		—	—
Bromine	lb.	.20 – .21	.21½ – .26
Calcium acetate	100 lbs.	1.75 – 2.00	..... – .....
Calcium carbide	lb.	.04½ – .04½	.05 – .05½
Calcium chloride, fused, lump	ton	24.00 – 24.50	24.75 – 27.00
Calcium chloride, granulated	lb.	.01½ – .02	.02½ – .02½
Calcium peroxide	lb.	..... –	1.40 – 1.50
Calcium phosphate, tribasic	lb.	..... –	.15 – .16
Camphor	lb.	..... –	.90 – .92
Carbon bisulphide	lb.	.06 – .06½	.06½ – .07½
Carbon tetrachloride, drums	lb.	.10½ – .10½	.11 – .12
Carbonyl chloride, (phosgene)	lb.	..... –	.60 – .75
Caustic potash (see potassium hydroxide)		..... –	..... – .....
Caustic soda (see sodium hydroxide)		..... –	..... – .....
Chalk, precip.—domestic, light	lb.	.04½ – .04½	..... – .....
Chalk, precip.—domestic, heavy	lb.	.03½ – .03½	..... – .....
Chalk, precip.—imported, light	lb.	.04½ – .05	—
Chlorine, gas, liquid-cylinders (100 lb.)	lb.	.06 – .06½	.06½ – .07
Chloroform	lb.	..... –	.37 – .40
Cobalt oxide	lb.	—	2.00 – 2.10
Copperas	ton	15.00 – 16.00	16.50 – 30.00
Copper carbonate, green precipitate	lb.	.19 – .20	.20½ – .21
Copper cyanide	lb.	—	.58 – .60
Copper sulphate, crystals	100 lb.	5.55 – 5.65	5.70 – 6.25
Cream of tartar	lb.	..... –	.23 – .24½
Epsom salt (see magnesium sulphate)		..... –	..... – .....
Ethyl acetate com. 85%	gal.	..... –	.60 – .65
Ethyl acetate, pure (acetic ether, 98% to 100%)	gal.	—	.93 – 1.00
Formaldehyde, 40 per cent.	lb.	.09 – .9½	.9½ – .10½
Fullers earth, f.o.b. mines	net ton	16.00 – 17.00	..... – .....
Fullers earth—imported powdered—net	ton	30.00 – 32.00	—
Fusel oil, ref.	gal.	..... –	2.50 – 3.00
Fusel oil, crude	gal.	..... –	1.40 – 1.75
Glauber's salt (see sodium sulphate)		..... –	..... – .....
Glycerine, c. p. drums extra	lb.	..... –	.16½ – .17
Iodine, resublimed	lb.	..... –	4.05 – 4.15
Iron oxide, red	lb.	..... –	.12 – .18
Lead acetate	lb.	—	.10 – .12
Lead arsenate, powd.	lb.	.15 – .15½	.15½ – .16½
Lead nitrate	lb.	—	.13 – .20
Litharge	lb.	.07½ – .07½	.08 – .08½
Magnesium carbonate, technical	lb.	.06 – .06½	.06½ – .08
Magnesium sulphate, U. S. P.	100 lb.	2.65 – 2.70	2.75 – 3.00
Magnesium sulphate, technical	100 lb.	..... –	1.00 – 1.80
Methanol, 95%	gal.	..... –	.57 – .58
Methanol, 97%	gal.	..... –	.59 – .60
Nickel salt, double	lb.	..... –	.11 – .11½
Nickel salt, single	lb.	..... –	.11 – .11½
Phosgene (see carbonyl chloride)		..... –	..... – .....
Phosphorus, red	lb.	.45 – .46	.47 – .50
Phosphorus, yellow	lb.	..... –	.30 – .35

		Carlots	Less Carlots
Potassium bichromate	lb.	.10 – .10½	.10½ – .10¾
Potassium bromide, granular	lb.	..... –	.13 – .17
Potassium carbonate, U. S. P.	lb.	.12 – .12½	.13 – .16
Potassium carbonate, 80–85%	lb.	.04 – .04½	.04½ – .05½
Potassium chlorate, crystals	lb.	.05½ – .06	.06½ – .08
Potassium cyanide	lb.	..... –	.42 – .45
Potassium hydroxide (caustic potash)	100 lb.	5.65 – 5.75	5.80 – 6.50
Potassium iodide	lb.	..... –	3.10 – 3.15
Potassium nitrate	lb.	.07½ – .07¾	.08 – .09
Potassium permanganate	lb.	.13 – .14	.14½ – .22
Potassium prussiate, red	lb.	nominal	nominal
Potassium prussiate, yellow	lb.	.25½ – .26	.26½ – .26½
Rochelle salts (see sodium potas. tartrate)		..... –	..... – .....
Salammoniac, white, granular	lb.	.06½ – .07	.07½ – .07¾
Salammoniac, gray, granular	lb.	.06½ – .06¾	.07 – .07½
Salsoda	100 lb.	1.60 – 1.70	1.75 – 2.00
Salt cake (bulk)	ton	17.00 –20.00	..... – .....
Soda ash, light	100 lb.	1.65 – 1.80	1.85 – 2.40
Soda ash, dense	100 lb.	1.75 – 1.85	1.90 – 2.40
Sodium acetate	lb.	.04 – .04½	.04½ – .05
Sodium bicarbonate	100 lb.	2.10 – 2.15	2.20 – 2.50
Sodium bichromate	lb.	.07½ – .08	.08½ – .08½
Sodium bisulphate (nitre cake)	ton	4.50 – 4.60	4.65 – 5.50
Sodium bisulphite powdered, U.S.P.	lb.	.04½ – .04½	.04½ – .05½
Sodium chlorate	lb.	.06½ – .06½	.07 – .07½
Sodium chloride	long ton	12.00 –13.00	..... – .....
Sodium cyanide	lb.	.22½ – .26	.26½ – .27½
Sodium fluoride	lb.	.09½ – .10	.10½ – .11
Sodium hydroxide (caustic soda)	100 lb.	3.35 – 3.40	3.45 – 4.00
Sodium hyposulphite	lb.	.03½ – .03½	.03½ – .04
Sodium nitrite	lb.	.08 – .08½	.08½ – .08½
Sodium peroxide, powdered	lb.	.28 – .30	.31 – .35
Sodium phosphate, dibasic	lb.	.03½ – .04	.04½ – .04½
Sodium potassium tartrate (Rochelle salts)	lb.	..... –	.18 – .21
Sodium prussiate, yellow	lb.	.18½ – .18½	.19 – .19½
Sodium silicate, solution (40 deg.)	100 lb.	.85 – 1.00	1.05 – 1.15
Sodium silicate, solution (60 deg.)	100 lb.	2.25 – 2.40	2.45 – 2.75
Sodium sulphate, crystals (glaubers salt)	100 lbs.	1.15 – 1.25	1.30 – 1.90
Sodium sulphide, fused, 60-62 per cent (cone.)	lb.	.04 – .04½	.04½ – .04½
Sodium sulphite, crystals	lb.	.03½ – .03½	.03½ – .04½
Strontium nitrate, powdered	lb.	.10 – .11	.11 – .15
Sulphur chloride, red	lb.	.05 – .05½	.05½ – .06
Sulphur, crude	ton	18.00 –20.00	..... – .....
Sulphur dioxide, liquid, cylinders extra	lb.	.08 – .08½	.09 – .10
Sulphur (sublimed), flour	100 lb.	..... –	2.25 – 3.10
Sulphur, roll (brimstone)	100 lb.	..... –	2.00 – 2.75
Talc—imported	ton	30.00 –40.00	..... – .....
Talc—domestic powdered	ton	18.00 –25.00	..... – .....
Tin bichloride	lb.	.09 – .09½	.09½ – .10
Tin oxide	lb.	..... –	.39 – .40
Zinc carbonate	lb.	.14 – .14½	.14½ – .15½
Zinc chloride, gran.	lb.	.08 – .08½	.08½ – .09
Zinc cyanide	lb.	.42 – .44	.45 – .47
Zinc oxide, XX	lb.	.07½ – .08	.08½ – .08½
Zinc sulphate	100 lb.	3.00 – 3.25	3.30 – 3.50

Coal-Tar Products

NOTE—The following prices are for original packages in large quantities:

Alpha-naphthol, crude	lb.	$1.00 — $1.05
Alpha-naphthol, refined	lb.	1.10 — 1.15
Alpha-naphthylamine	lb.	.28 — .30
Aniline oil, drums extra	lb.	.16½ — .17
Aniline salts	lb.	.24 — .26
Anthracene, 80% n drums (100 lb.)	lb.	.75 — 1.00
Benzaldehyde U.S.P.	lb.	1.30 — 1.35
Benzidine, base	lb.	.85 — .95
Benzidine sulphate	lb.	.75 — .85
Benzoic acid, U.S.P.	lb.	.60 — .65
Benzoate of soda, U.S.P.	lb.	.55 — .57
Benzene, pure, water-white, in drums (100 gal.)	gal.	.29 — .35
Benzene, 90%, in drums (100 gal.)	gal.	.27 — .32
Benzyl chloride, 95-97%, refined	lb.	.25 — .27
Benzyl chloride, tech	lb.	.20 — .23
Beta-naphthol benzoate	lb.	3.75 — 4.00
Beta-naphthol, sublimed	lb.	.60 — .65
Beta-naphthol, tech	lb.	.28 — .30
Beta-naphthylamine, sublimed	lb.	1.50 — 1.60
Cresol, U. S. P., in drums (100 lb.)	lb.	.15 — .16
Ortho-cresol, in drums (100 lb.)	lb.	.18 — .20
Cresylic acid, 97–99%, straw color, in drums	gal.	.50 — .52
Cresylic acid, 95-97%, dark, in drums	gal.	.45 — .47
Dichlorbenzene	lb.	.06 — .09
Diethylaniline	lb.	1.05 — 1.10
Dimethylaniline	lb.	.39 — .41
Dinitrobenzene	lb.	.21 — .25
Dinitroclorbenzene	lb.	.25 — .27
Dinitronaphthalene	lb.	.32 — .35
Dinitrophenol	lb.	.35 — .38
Dinitrotoluene	lb.	.23 — .25
Dip oil, 25%, car lots, in drums	gal.	.24 — .25
Diphenylamine	lb.	.60 — .70
H-acid	lb.	.90 — 1.00
Meta-phenylenediamine	lb.	1.00 — 1.05
Monochlorbenzene	lb.	.10 — .12
Monoethylaniline	lb.	1.15 — 1.20
Naphthalene crushed, in bbls.	lb.	.06½ — .07
Naphthalene, flake	lb.	.06½ — .07½
Naphthalene, balls	lb.	.07½ — .08½
Naphthionic acid, crude	lb.	.65 — .70
Nitrobenzene	lb.	.10 — .12
Nitro-naphthalene	lb.	.30 — .35
Nitro-toluene	lb.	.15 — .17½
Ortho-amidophenol	lb.	2.75 — 2.80
Ortho-dichlor-benzene	lb.	.15 — .20
Ortho-nitro-phenol	lb.	.75 — .80
Ortho-nitro-toluene	lb.	.15 — .20
Ortho-toluidine	lb.	.20 — .25
Para-amidophenol, base	lb.	1.25 — 1.30
Para-amidophenol, HCl	lb.	1.30 — 1.35
Para-dichlorbenzene	lb.	.17 — .18
Paranitroaniline	lb.	.77 — .80
Para-nitrotoluene	lb.	.70 — .75
Para-phenylenediamine	lb.	1.50 — 1.55
Para-toluidine	lb.	1.10 — 1.15
Phthalic anhydride	lb.	.35 — .38
Phenol, U. S. P., drums	lb.	.11½ — .15
Pyridine	gal.	1.75 — 2.75
Resorcinol, technical	lb.	1.25 — 1.30
Resorcinol, pure	lb.	1.85 — 2.00
Salicylic acid, tech., in bbls.	lb.	.18 — .20
Salicylic acid, U. S. P.	lb.	.22 — .23
Salol	lb.	.80 — .82
Solvent naphtha, water-white, in drums, 100 gal.	gal.	.25 — .28
Solvent naphtha, crude, heavy, in drums, 100 gal.	gal.	.12 — .14
Sulphanilic acid, crude	lb.	.25 — .27
Tolidine	lb.	1.20 — 1.30
Toluidine, mixed	lb.	.32 — .38
Toluene, in tank cars	gal.	.25 — .28
Toluene, in drums	gal.	.30 — .35
Xylidines, drums, 100 gal.	lb.	.40 — .45
Xylene, pure, in drums	gal.	.40 — .45
Xylene, pure, in tank cars	gal.	.45 — .....
Xylene, commercial, in drums, 100 gal.	gal.	.33 — .35
Xylene, commercial, in tank cars	gal.	.30 — .....

Waxes

Prices based on original packages in large quantities.

Bayberry Wax	lb.	$0.20 — $0.21
Beeswax, refined, dark	lb.	.25 — .26
Beeswax, refined, light	lb.	.30 — .32
Beeswax, white pure	lb.	.35 — .38
Candellila wax	lb.	.24 — .25
Carnauba, No. 1	lb.	.45 — .46
Carnauba, No. 2, North Country	lb.	.24 — .24½
Carnauba, No. 3, North Country	lb.	.14½ — .15
Japan	lb.	.19 — .20
Montan, crude	lb.	.05 — .05½
Paraffine waxes, crude match wax (white) 105-110 m.p.	lb.	.04½ — .04½
Paraffine waxes, crude, scale 124-126 m.p.	lb.	.02½ — .....
Paraffine waxes, refined, 118-120 m.p.	lb.	.03½ — .03½
Paraffine waxes, refined, 125 m.p.	lb.	.03½ — .03½
Paraffine waxes, refined, 128-130 m.p.	lb.	.04 — .04½
Paraffine waxes, refined, 133-135 m.p.	lb.	.04½ — .05
Paraffine waxes, refined, 135-137 m.p.	lb.	.05½ — .05½
Stearic acid, single pressed	lb.	.08½ — .09
Stearic acid, double pressed	lb.	.09½ — .09½
Stearic acid, triple pressed	lb.	.10½ — .10½

Naval Stores

All prices are f.o.b. New York unless otherwise stated, and are based on carload lots. The oils in 50-gal. bbls., gross weight, 500 lb.

Rosin B-D, bbl.	280 lb.	$5.30 —	5.35
Rosin E-I	280 lb.	5.40 —	5.45
Rosin K-N	280 lb.	6.05 —	6.80
Rosin W. G.-W. W	280 lb.	7.00 —	7.25
Wood rosin, bbl.	280 lb.	6.25 —	.....
Spirits of turpentine	gal.	.89½ —	.....
Wood turpentine, steam dist.	gal.	.87 —	.....
Wood turpentine, dest. dist.	gal.	.86 —	.....
Pine tar pitch, bbl.	200 lb.	..... —	6.00
Tar, kiln burned, bbl. (500 lb.)	bbl.	..... —	10.00
Retort tar, bbl.	500 lb.	—	9.00
Rosin oil, first run	gal.	.36 —	.....
Rosin oil, second run	gal.	.39 —	.....
Rosin oil, third run	gal.	.46 —	.....
Pine oil, steam dist., sp.gr., 0.930-0.940	gal.		$1.90
Pine oil, pure, dest. dist.	gal.		1.50
Pine tar oil, ref., sp.gr. 1.025-1.035	gal.		.46
Pine tar oil, crude, sp.gr. 1.025-1.035 tank cars f.o.b. Jacksonville, Fla.	gal.		.35
Pine tar oil, double ref., sp.gr. 0.965-0.990	gal.		.75
Pine tar, ref., thin, sp.gr., 1.080-1.960	gal.		.35
Turpentine, crude, sp. gr., 0.900-0.970	gal.		1.25
Hardwood oil, f.o.b. Mich., sp.gr., 0.960-0.990	gal.		.35
Pinewood creosote, ref.	gal.		.52

Fertilizers

Ammonium sulphate, bulk	100 lb.	$2.60 —	2.70
Blood, dried, f.o.b., N. Y.	unit	4.00	
Bone, 3 and 50, ground, raw	ton	30.00 —	32.00
Fish scrap, dom., dried, f.o.b. works	unit	3.10 —	3.20
Nitrate soda	100 lb.	2.45 —	2.50
Tankage, high grade, f.o.b. Chicago	unit	3.25 —	3.40
Phosphate rock, f.o.b. mines, Florida pebble, 68-72%	ton	5.50 —	7.00
Tennessee, 78-80%	ton	8.50 —	9.00
Potassium muriate, 80%	ton	34.00 —	37.00
Potassium sulphate	unit	1.00 —	.....

Crude Rubber

Para—Upriver fine	lb.	$0.17½ —	.18
Upriver coarse	lb.	.12½ —	.13
Upriver caucho ball	lb.	.12 —	.12½
Plantation—First latex crepe	lb.	.15 —	.15½
Ribbed smoked sheets	lb.	.15½ —	.15½
Brown crepe, thin, clean	lb.	.13 —	.....
Amber crepe No. 1	lb.	.15 —	.....

Oils

VEGETABLE

The following prices are f.o.b. New York for carload lots.

Castor oil, No. 3, in bbls.	lb.	$0.10 —	$0.10½
Castor oil, AA, in bbls.	lb.	.11½ —	.12
China wood oil, in bbls.	lb.	.14 —	.14½
Cocoanut oil, Ceylon grade, in bbls.	lb.	.08½ —	.09
Cocoanut oil, Cochin grade, in bbls.	lb.	.09½ —	.10
Corn oil, crude, in bbls.	lb.	.08½ —	.08½
Cottonseed oil, crude (f. o. b. mill)	lb.	.09½ —	.09¾

Cottonseed oil, summer yellow	lb.	.10½ —	.11
Cottonseed oil, winter yellow	lb.	.11¼ —	.11½
Linseed oil, raw, car lots (domestic)	gal.	.86 —	.87
Linseed oil, raw, tank cars (domestic)	gal.	.83 —	.84
Linseed oil, in 5-bbl lots (domestic)	gal.	.90 —	.91
Olive oil, denatured	gal.	1 10 —	1.12
Palm, Lagos	lb.	.08¼ —	.08½
Palm, Niger	lb.	.06¼ —	.06½
Peanut oil, crude, tank cars (f.o.b. mill)	lb.	.09 —	.09¼
Peanut oil, refined, in bbls	lb.	.11¼ —	.11½
Rapeseed oil, refined in bbls	gal.	.83 —	.84
Rapeseed oil, blown, in bbls	gal.	.88 —	.89
Soya bean oil (Manchurian), in bbls, N. Y.	lb.	.09½ —	....
Soya bean oil, tank cars, f.o.b., Pacific coast	lb.	.08 —	....

FISH

Light pressed menhaden	gal.	$0.48 —	....
Yellow bleached menhaden	gal.	.51 —	....
White bleached menhaden	gal.	.50 —	....
Blown menhaden	gal.	.57 —	....

Miscellaneous Materials

All f.o.b. New York Unless Otherwise Stated

Asbestos, crude No. 1, f.o.b., Quebec, Canada	short ton	$1,000.00	$1,200.00
Asbestos, shingle stock, f.o.b., Quebec, Canada	short ton	80.00 —	125.00
Asbestos, cement stock, f.o.b., Quebec, Canada	short ton	12.50 —	17.50
Barytes, ground, white, f.o.b. mills	net ton	23.00—	209
Barytes, ground, off color f.o.b. mills	net ton	17.00 —	21.50
Barytes, floated, f.o.b. St. Louis	net ton	23.00 —	24.00
Barytes, crude f.o.b. mines	net ton	6.00 —	7.00
Casein	lb.	.15 —	.16
China clay (kaolin) crude, f.o.b. mines, Georgia	net ton	6.00 —	8.00
China clay (kaolin) washed, f.o.b. Georgia	net ton	8.00 —	10.00
China clay (kaolin) powdered, f.o.b. Georgia	net ton	12.00 —	20.00
China clay (kaolin) crude f.o.b. Virginia points	net ton	8.00 —	12.00
China clay (kaolin)ground, f.o.b. Virginia points	net ton	13.00 —	20.00
China clay (kaolin), imported, lump	net ton	14.00 —	20.00
China clay (kaolin), imported, powdered	net ton	30.00 —	35.00
Feldspar, No. 1 pottery grade	long ton	6.50 —	6.75
Feldspar, No. 2 pottery grade	long ton	5.75 —	5.90
Feldspar, No. 1 soap grade	long ton	7.25 —	7.50
Feldspar, No. 1 Canadian, for mill	long ton	22.00 —	22.50
Graphite, Ceylon lump, first quality	lb.	.04½ —	.06½
Graphite, Ceylon chip	lb.	.03½ —	.05
Graphite, high grade amorphous crude	lb.	.00½ —	.02½
Kieselguhr, f.o.b. mines, Cal.	per ton	40.00 —	....
Kieselguhr, f.o.b. N. Y.	per ton	55.00 —	60.00
Magnesite, calcined (crude)	per ton	12.00 —	15.00
Pumice stone, imported	lb.	.03 —	.40
Pumice stone, domestic, lump	lb.	.05 —	.05½
Pumice stone, domestic, ground	lb.	.06 —	.07
Shellac, orange fine	lb.	.75 —	.76
Shellac, orange superfine	lb.	.77 —	.78
Shellac, A. C. garnet	lb.	.64 —	.65
Shellac, T. N.	lb.	.73 —	.74
Silica, glass sand, f.o.b. Indiana	per ton	1.25 —	1.50
Silica, sand blast material, f.o.b. Indiana	per ton	2.25 —	4.50
Silica, amorphous, 250 mesh, f.o.b. Illinois	per ton	14.00 —	14.50
Silica, building sand, f.o.b. Pa.	per ton	2.25 —	3.00
Soapstone	ton	12.00 —	15.00
Talc, 200 mesh, f.o.b. Vermont	ton	7.00 —	12.00
Talc, 200 mesh, f.o.b. Georgia	ton	8.25 —	13.00
Talc, 200 mesh, f.o.b. Los Angeles	ton	16.00 —	20.00

Refractories

Bauxite brick, 56% Al, f.o.b. Pittsburgh	per 1,000	$130.00
Carborundum refractory brick, 9-in.	1,000	1100.00
Chrome brick, f.o.b. Eastern shipping points	net ton	41–44
Chrome cement, 40-50% Cr_2O_3	net ton	30–32
Chrome cement, 40-45% Cr_2O_3, sacks, in car lots, f.o.b. Eastern shipping points	net ton	30–32
Fireclay brick, 1st quality, 9-in. shapes, f.o.b. Pennsylvania, Ohio and Kentucky works	1,000	32–37
Fireclay brick, 2nd quality, 9-in. shapes, f.o.b. Pennsylvania, Ohio and Kentucky works	1,000	27–30
Magnesite brick, 9-in. straight (f.o.b. works)	net ton	53–55
Magnesite brick, 9-in. arches, wedges and keys	net ton	70
Magnesite brick, soaps and splits	net ton	90
Silica brick, 9-in. sizes, f.o.b. Chicago district	1,000	35–37
Silica brick, 9-in. sizes, f.o.b. Birmingham district	1,000	37–39
Silica brick, 9-in. sizes, f.o.b. Mt. Union, Pa.	1,000	27–30

Ferro-Alloys

All f.o.b. Works

Ferrocarbon-titanium, 15-18%, f.o.b. Niagara Falls, N. Y.	net ton	$200.00 —	$225.00
Ferrochromium, per lb. of Cr contained, 6-8% carbon, carlots	lb.	.11½—	....
Ferrochromium, per lb. of Cr contained, 4-6% carbon, carlots	lb.	.12 —	....
Ferromanganese, 76-80% Mn, domestic	gross ton	59.00 —	60.00
Ferromanganese, 78-82% Mn, English and German c. i. f. Atlantic seaport	gross ton	58.00 —	62.50
Spiegeleisen, 18-22% Mn	gross ton	30.00 —	32.00
Ferromolybdenum, 50-60% Mo, per lb. of Mo	lb.	2.25 —	....
Ferrosilicon, 10-15%	gross ton	38.00 —	40.00
Ferrosilicon, 50%	gross ton	54.00 —	55.00
Ferrosilicon, 75%	gross ton	115.00 —	120.40
Ferrotungsten, 70-80%, per lb. of contained W	lb.	.37 —	.50
Ferro-uranium, 35-50% of U, per lb. of U content	lb.	6.00 —	....
Ferrovanadium, 30-40% per lb. of contained V.	lb.	4.00 —	4.25

Ores and Semi-finished Products

All f.o.b. New York, Unless Otherwise Stated

Bauxite, 52% Al content	net ton	$6.00 —	$12.00
Chrome ore, Calif. concentrates, 50% min. Cr_2O_3	ton	21.00 —	22.00
Chrome ore, 50% Cr_2O_3, f.o.b. Atlantic seaboard	ton	20.00 —	27.00
Coke, foundry, f.o.b. ovens	net ton	3.75 —	4.25
Coke, furnace, f.o.b. ovens	net ton	2.85 —	3.00
Fluorspar, gravel, f.o.b. mines, New Mexico	net ton	12.00 —	....
Fluorspar, standard, domestic washed gravel Kentucky and Illinois mines	net ton	20.00 —	22.00
Ilmenite, 52% TiO_2, per lb. ore	lb.	.01½—	.01½
Manganese ore, 50% Mn, c.i.f. Atlantic seaport	unit	.23 —	.25
Manganese ore, chemical (MnO_2)	net ton	55.00 —	60.00
Molybdenite, 85% MoS_2, per lb. of MoS_2, N. Y.	lb.	.48 —	.50
Monazite, per unit of ThO_2, c.i.f., Atlantic seaport	unit	27.00 —	....
Pyrites, Spanish, fines, c.i.f., Atlantic seaport	unit	.12 —	.12
Pyrites, Spanish, furnace size, c.i.f. Atlantic seaport	unit	.13 —	.13
Pyrites, domestic, fines, f.o.b. mines, Ga.	unit	.11 —	.12
Rutile, 95% TiO_2 per lb. ore	lb.	.12 —	....
Tungsten, scheelite, 60% WO_3 and over, per unit of WO_3 (nominal)	unit	2.25 —	2.50
Tungsten, wolframite, 60% WO_3 and over, per unit of WO_3, N. Y. C.	unit	2.50 —	2.75
Uranium ore (carnotite) per lb. of U_3O_8	lb.	1.25 —	1.75
Uranium oxide, 96% per lb. contained U_3O_8	lb.	2.25 —	2.50
Vanadium pentoxide, 99%	lb.	12.00 —	14.00
Vanadium ore, per lb. of V_2O_5 contained	lb.	1.00 —	....
Zircon, washed, iron free, f.o.b. Pablo, Florida	lb.	.04½—	.13½

Non-Ferrous Metals

New York Markets

	Cents per Lb.
Copper, electrolytic	12.875
Aluminum, 98 to 99 per cent	19.00
Antimony, wholesale lots, Chinese and Japanese	4.40
Nickel, ordinary (ingot)	41.00
Nickel, electrolytic	44.00
Nickel, electrolytic, resale	32.00
Monel metal, shot and blocks	35.00
Monel metal, ingots	38.00
Monel metal, sheet bars	40.00
Tin, 5-ton lots, Straits	29.25
Lead, New York, spot	4.70
Lead, E. St. Louis, spot	4.40
Zinc, spot, New York	4.925–4.95
Zinc, spot, E. St. Louis	4.475–4.50

OTHER METALS

Silver (commercial)	oz.	$0.65½
Cadmium	lb.	1.00–1.10
Bismuth (500 lb. lots)	lb.	2.00@2.10
Cobalt	lb.	3.00@3.25
Magnesium (f.o.b. Philadelphia)	lb.	1.25
Platinum	oz.	85.00@ 90.00
Iridium	oz.	170.00@190.00
Palladium	oz.	55.00@ 60.00
Mercury	75 lb.	49.00

FINISHED METAL PRODUCTS

	Warehouse Price Cents per Lb.
Copper sheets, hot rolled	19.25
Copper bottoms	28.25
Copper rods	19.25
High brass wire	16.75
High brass rods	14.25
Low brass wire	18.25
Low brass rods	18.75
Brazed brass tubing	23.00
Brazed bronze tubing	28.00
Seamless copper tubing	20.75
Seamless high brass tubing	18.80

OLD METALS—The following are the dealers' purchasing prices in cents per pound:

	New York Current
Copper, heavy and crucible	10.25@10.50
Copper, heavy and wire	10.00@10.25
Copper, light and bottoms	7.75@ 8.25
Lead, heavy	3.60@ 3.85
Lead, tea	3.00@ 3.25
Brass, heavy	4.50@ 4.75
Brass, light	4.00@ 4.25
No. 1 yellow brass turnings	4.00@ 4.25
Zinc	2.25@ 2.50

Structural Material

The following base prices per 100 lb. are for structural shapes 3 in. by ¼ in. and arger, and plates ¼ in. and heavier, from jobbers' warehouses in the cities named:

	New York*	Cleveland	Chicago
Structural shapes	$2.63	$2.63	$2.63
Soft steel bars	2.53	2.53	2.53
Soft steel bar shapes	2.53	2.53	2.53
Soft steel bands	3.13	3.13	3.13
Plates, ¼ to 1 in. thick	2.63	2.63	2.63

*Add 15c per 100 lb. for trucking to Jersey City and 10c for delivery in New York and Brooklyn.

Industrial

Financial, Construction and Manufacturers' News

Construction and Operation

Arkansas

ASHDOWN—The White Cliff Products Co., recently organized to operate in the White Cliffs section, will commence immediately the construction of a crushing and pulverizing plant for the manufacture of whiting, fertilizer and kindred products. It will have a capacity of about 15 tons an hour, and is estimated to cost close to $100,000. Work is under way on a power plant at the property. The company is headed by A. B. Banks, Little Rock, Ark. The Ashdown Chamber of Commerce is interested in the project.

California

NEWPORT BEACH—The Council has called a special election for April 10, to vote bonds for extensions to the municipal artificial gas plant, for reserve supply, to cost about $75,000. Paul E. Kressly, H. W. Hellman Bldg., Los Angeles, is city engineer.

Georgia

PERRY—The Council will install a new filtration plant in connection with an improved waterworks system, plans for which have been prepared by O. H. Sheffield, 505 Peachtree St., Atlanta, Ga., engineer. S. P. Crowell is city clerk.

MACON—The Buckeye Cotton Oil Co., is planning for the erection of a new oil mill on local site. Plans will be prepared at an early date.

SAVANNAH—The Savannah Gas Co. is planning for extensions and improvements in its plant on East Broad St., to cost about $50,000. John W. Golden is vice-president and general manager.

Illinois

EAST ST. LOUIS—The Obear-Nestor Glass Co., 25 North 2nd St., St. Louis, Mo., has excavations under way for the erection of its proposed 1-story plant addition at Broadway and Belt St., to cost about $75,000. It will be equipped for the manufacture of glass bottles.

CHICAGO—The Dryden Rubber Co., 1014 South Kildare Ave., has filed plans for the erection of a 1-story extension, 20 x 77 ft.

Maryland

BALTIMORE—The Holtite Mfg. Co., Warner and Ostend Sts., manufacturer of rubber products, is planning for the erection of a 1-story addition to double the present capacity. Morris Eisen is president and general manager.

Massachusetts

PEABODY—The Hunt Rankin Co., manufacturer of suede leathers, etc., is completing the erection of a 4-story addition, and will place the factory in operation at an early date.

SOUTHBORO—The Dennison Mfg. Co., Framingham, Mass., manufacturer of paper specialties, is having plans prepared for the erection of a 4-story plant, 70 x 300 ft., at Southboro. Monks & Johnson, 99 Chauncey St., Boston, are architects.

WORCESTER—The United States Peat Products Co., recently organized with a capital of $99,000, is considering tentative plans for the establishment of a color pigment manufacturing plant in connection with the development of peat properties. Edmund P. Cummins, Worcester, is treasurer.

BOSTON—The B. O. & G. C. Wilson Co., 196 Cambridge St. manufacturer of chemicals, drugs, etc., is taking bids for the erection of a 5-story plant, 60 x 200 ft., on Farwell St., Waltham, Mass. The H. M. Hope Engineering Co., 185 Devonshire St., Boston, is engineer.

Michigan

CADILLAC—The Cadillac Lumber & Chemical Co. has plans under way for the erection of a new plant at Sault Ste. Marie, Mich. The present works will be removed to this location.

MT. PLEASANT—The National Portland Cement Co. is completing plans for its proposed new 2-story cement manufacturing plant at Coldwater Lake, Mich., and will commence erection in April. It is estimated to cost about $500,000, including machinery. H. C. Shields is general manager.

ALPENA—The Kelley Island Stone & Lime Co. has acquired the plant of the Great Lakes Stone & Lime Co., at Rockport, and plans for extensive operations at the property. The present plant consists of two crushers, with total capacity of about 12,000 tons per day of 10 hours. The site comprises approximately 1,500 acres of property.

DETROIT—Plans are being completed by the Board of Water Commissioners for the construction of a filtration plant for the city waterworks at Waterworks Park, estimated to cost in excess of $2,000,000. Theodore A. Leisen is engineer. H. S. Starkey, 176 East Jefferson Ave., is secretary.

KALAMAZOO—The Kalamazoo Paper Box Co. has commenced the construction of a new plant to cost in excess of $150,000, including machinery. Robert E. Staebler is secretary, treasurer and general manager.

Missouri

KANSAS CITY—The Fleischmann Yeast Co. has acquired the plant of the Liberty Yeast Co., at North Kansas City, now in course of erection. It will be completed at once, with estimated cost of about $350,000. The factory will have a daily capacity of about 15,000 lb. of yeast.

ST. LOUIS—A large filtration plant will be installed at the city waterworks in connection with a number of extensions and improvements, estimated to cost in excess of $5,000,000. An election to vote bonds will be held during the summer. Edward E. Wall is city water commissioner.

New Jersey

TRENTON—Fire, Feb. 17, destroyed the plant of the Vulcan Recovery Co., May and Beakes Sts., manufacturer of reclaimed rubber products, with loss estimated at about $100,000, including equipment.

New York

SYRACUSE—The Syracuse Pottery Co., 711 East Division St., has tentative plans under consideration for the erection of a new plant at Amboy, near Syracuse.

BROOKLYN—J. M. Huber, 602 62nd St., manufacturer of colors, is taking bids for the erection of a 2-story plant addition, 36 x 52 ft., at 62nd St. and 6th Ave.

North Carolina

HENDERSONVILLE—A filtration plant will be installed at the new city waterworks, estimated to cost about $400,000, complete. Bonds have been issued. The Gilbert C. White Co., Durham, N. C., is engineer. C. E. Brooks is chairman of the Water Committee.

SALISBURY—The Arey Brick & Lumber Co., recently organized, will install a new drier system and make other improvements at its local brick-manufacturing plant. The company will operate with a capital of $100,000. F. M. Tyack is secretary and treasurer.

CHARLOTTE—The Council is planning for extensions and improvements in the municipal water gas plant, to cost about $40,000, to include a new tar extractor and equipment to increase the output from 15,000 to 25,000 cu.ft. per hour.

Pennsylvania

PHILADELPHIA—The Moore White Co., 15th St. and Lehigh Ave., manufacturer of iron and steel castings, etc., has commenced the erection of a 2-story foundry addition, 60 x 165 ft., estimated to cost close to $35,000.

YORK—The Ford Roofing Products Co., manufacturer of asbestos roofing, is completing plans for enlargements in its plant to double the present output. Work will be commenced at an early date.

PHILADELPHIA—The Wittman Moriarty Co., 4th and Vine Sts., manufacturer of leather products, has awarded a contract to William F. Newberry, 112 South 16th St., for the erection of a 1- and 2-story addition to its tannery at Ontario and C Sts., 75 x 105 ft. Furness, Evans & Co., 315 South 15th St., are architects.

LANCASTER—The Armstrong Cork Co. has construction under way on a 1-story addition to its local plant at Mary and Liberty Sts., 30 x 50 ft.

Tennessee

MEMPHIS—The Kot-N-Wood Products Co. has work under way on a new plant on local site for the manufacture of fiber paving brick, wallboard and kindred composition products, utilizing treated waste cotton stalks as basic material. The initial brick plant will have a capacity of 3,600 bricks per hour, with building 60 x 240 ft. George B. Stryker is president. William D. Edwards is engineer in charge.

LAFOLLETTE—The LaFollette Coal & Iron Co. has preliminary plans in preparation for the erection of its proposed new fuel-carbonizing plant. Parker & Wilder, Cincinnati, O., are architects. S. S. Pratt is assistant general manager.

Texas

DALLAS—The Trinity Paper Mills Co., Commerce, Tex., operating a local pulp mill, has acquired property at 3010 Williams St., Dallas, as a site for the erection of a new 1-story plant for the manufacture of waxed paper specialties. A subsidiary company will be organized to operate the factory, with J. Y. Webb and J. M. Irwin, officials of the Trinity company, as president and vice-president, respectively.

ROCKDALE—The Douglass Drilling Co. will commence the immediate erection of a new oil refinery to handle crude oil from its Rockdale-Tracy leases. It will be built on the unit plan, with first unit to have a capacity of 15 bbl. per day. A lubricating oil and grease plant will also be established.

Virginia

WINCHESTER—The American Gas Improvement Co., 2 Rector St., New York, N. Y., is planning for extensions and improvements in its local gas plant to cost about $150,000. A new electrochemical gas-manufacturing process will be installed.

RICHMOND—A new purification and filtration plant will be installed in connection with extensions and improvements to be made to the city waterworks, estimated to cost about $1,500,000. The Water Department is in charge.

West Virginia

BELLE—The Belle Alkali Co. is perfecting plans for the erection of its proposed plant addition, to be used for the manufacture of caustic soda, chlorine and kindred products. D. W. Stubberfield is manager.

FAIRMONT—The Board of Water Commissioners is planning for the installation of a filtration plant at the city waterworks, with capacity of about 4,000,000 gal. per day. S. B. Miller is city engineer.

Wisconsin

MILWAUKEE—The Red Star Yeast & Products Co., has taken bids for the erection of a new experimental plant, 25 x 40 ft. E. R. Liebert, Milwaukee, is architect.

OCONTO FALLS—The Falls Mfg. Co. has preliminary plans under consideration for the erection of a 1-story paper mill, 60 x 200 ft., estimated to cost about $150,000, including machinery. Frank Cota is secretary.

Capital Increases, etc.

THE LOUISVILLE CEMENT CO., Louisville, Ky., has filed notice of increase in capital from $850,000 to $2,100,000.

THE DUNN OIL CO., Kansas City, Mo., has filed notice of increase in capital from $400,000 to $1,000,000.

THE MACDOUGALL PROCESS CO., Niagara Falls, N. Y., has filed notice of change of name to the Rowe Paint & Varnish Co.

THE MITCHELL-RAND MFG. CO., 18 Vesey St., New York, N. Y., manufacturer of insulation products, has filed notice of reduction in capital from $200,000 to $155,000.

THE PETOSKEY PORTLAND CEMENT CO., Petoskey, Mich., has filed notice of increase in capital from $1,500,000 to $2,500,000.

Percival Wilds has been appointed receiver for the HERCULES PAPER CORP., 135

Broadway, New York, N. Y., manufacturer of paper products, in bond of $25,000. The liabilities are stated to be $1,790,509, and book value of assets, $3,315,487. The same receiver has also been appointed for the company's subsidiaries, the FRANK GILBERT PAPER CO. and the UNION WAXED & PARCHMENT PAPER CO.

THE DURST MFG. CO., 119 Chambers St., New York, N. Y., manufacturer of rubber products, has filed notice of increase in capital from $100,000 to $400,000.

THE CALIFORNIA & HAWAIIAN SUGAR REFINING CORP., Crockett, Cal., operating a local refinery, has arranged for a bond issue of $7,000,000, for general operations. Andrew Welch is president.

THE GREEN BAY PAPER & FIBER CO. and the JOHN HOBERG CO., both of Green Bay, Wis., manufacturers of paper and fiber products, have filed notice of merger. Operations will be continued as heretofore at the two mills.

New Companies

THE SUPERIOR CRYSTAL CO., Newark, N. J., has been incorporated with a capital of $25,000, to manufacture soaps and kindred products. The incorporators are A. Leiberman, Benjamin Burden and Solomon Halperin, 109 South 20th St., Newark.

THE BAXTER PAPER CORP., New York, N. Y., has been incorporated with a capital of $100,000, to manufacture paper products. The incorporators are H. L. Bunker, I. Baxter and H. J. Wellebil. The company is represented by Graves, Miles & Yawger, 111 Broadway, New York.

THE CRAINE-SCHRAGE STEEL CO., Detroit, Mich., has been incorporated with a capital of $150,000, to manufacture steel castings and other steel products. The incorporators are C. P. Craine, Arthur A. and W. C. Schrage, 965 Devonshire Ave., Detroit.

THE MULBER OIL CO., Pawhuska, Okla., has been incorporated with a capital of $200,000, to manufacture petroleum products. The incorporators are William W. Cruber, Pawhuske; H. C. Durnell, Bartlesville, Okla.; and R. V. McMullen, Eureka, Kan.

THE AROMO MFG. CO., 740 West North Ave., Baltimore, Md., has been incorporated with a capital of $100,000, to manufacture chemicals, chemical compounds, drugs, etc. The incorporators are Arthur W. Smith, Norris Bernstein and Albert Paltieloff.

THE RAY D'OR CHEMICAL CO., Scranton, Pa., has been incorporated with a capital of $10,000, to manufacture chemicals and chemical byproducts. J. Harold Clarke, Scranton, is treasurer.

THE FAIRFIELD SHEET GLASS CO., Wilmington, Del., has been incorporated under state laws with capital of $800,000, to manufacture glass. The company is represented by the Corporation Trust Co. of America, du Pont Bldg., Wilmington.

THE BERGEN LABORATORY PRODUCTS CO., 142 Market St., Newark, N. J., has filed notice of organization to manufacture chemicals and chemical compounds. The company is headed by Joseph F. Papscoe, 800 South 19th St., Newark.

T. A. DESMOND & CO., INC., New York, N. Y., has been incorporated with a capital of $600,000, to manufacture rubber products, gutta percha goods, etc. The incorporators are T. A. Desmond, H. S. Delanie and F. M. Tienken. The company is represented by Murray, Prentice & Aldrich, 37 Wall St.

THE INTERNATIONAL REFINING & MFG. CO., Greenleaf and Hartrey Sts., Evanston, Ill., has been incorporated with a capital of $500,000, to manufacture refined petroleum products. The incorporators are E. R. and William O. Jeffery, Sr. and Jr.

THE WHITE CO., 206 Water St., Baltimore, Md., has been incorporated with a capital of $100,000, to manufacture chemicals, varnishes, paints, etc. The incorporators are I. and Earl A. Constam, and G. M. Stengle. The company has plans under way for the erection of a new plant.

THE VIRGINIA SOUTHERN OIL CORP., Wilmington, Del., has been incorporated under state laws with a capital of $750,000, to manufacture petroleum products. The company is represented by the Corporation Service Co., Wilmington.

THE MELITE CORP., New York, N. Y., has been incorporated with a capital of $25,000, to manufacture carbon black, compounds, etc. The incorporators are J. M. Stower and J. C. Woodruff. The company is represented by H. G. Baker, attorney, Plattsburg, N. Y.

THE ARCHER PHOSPHATE DEVELOPMENT CO., Archer, Fla., has been incorporated with a capital of $75,000, to operate phosphate properties, manufacture fertilizers, etc. W. F. Walker is president, and S. G. Moyes, vice-president, both of Archer.

THE S. & S. MFG. CO., Columbia, Pa., has been incorporated with a capital of $10,000, to manufacture iron, steel and other metal castings. Samuel A. Stape, Columbia, is treasurer.

THE SYRACUSE CONSUMERS' OIL CO., Syracuse, N. Y., has been incorporated with a capital of $50,000, to manufacture oil products. The incorporators are H. F. Schoonmaker, W. A. Wright and L. C. Helms. The company is represented by J. B. Neily, Gurney Bldg., Syracuse.

THE LUMINITE CORP., Newark, N. J., has been incorporated with a capital of $100,000, to manufacture chemicals and chemical byproducts. The incorporators are Carl T. Fregens, M. Burgesser and John A. Bernard, 753 Broad St., Newark.

THE CELLULOSE PRODUCTS CO., INC., 1119 Fidelity Bldg., Baltimore, Md., has been incorporated with a capital of 100,000 shares of stock, no par value, to manufacture pyroxylin products, composition specialties, etc. The incorporators are Edward M. and E. H. Hammond, and R. Bennett Darnall.

THE BRAZOS VALLEY OIL CO., New York, N. Y., has been incorporated under Delaware laws with capital of $6,000,000, to manufacture petroleum products. The company is represented by the United States Corporation Co., 65 Cedar St., New York.

THE POMPEIAN ROMANZA CORP., Fayette and 11th Sts., Highlandtown, Baltimore, Md., has been incorporated with a capital of $1,760,000, to manufacture edible oils, compounds, etc. The incorporators are W. W. Cook, W. H. Hamilton and W. H. Cook.

THE PRESTO LEATHER PRODUCTS CORP., Brooklyn, N .Y., has been incorporated with a capital of $10,000, to manufacture leather goods. The incorporators are J. Pressman, M. L. and F. Weissman. The company is represented by Leo Rosenberg, 200 Broadway, New York.

THE D. P. O'BRIEN CO., INC., Camden, N. J., has been incorporated with a capital of $20,000, to manufacture chemical compounds, drugs, etc. The company is represented by the Corporation Guarantee & Trust Co., 419 Market St., Camden.

THE DRAKE OIL CO., 30 North Michigan Ave., Chicago, Ill., has been incorporated under state laws to manufacture petroleum products. The incorporators are Frank H. Pitkin, William Mannhardt and Charles O'Hare.

THE ALABAMA MICA CO., Heflin, Ala., has been incorporated with a capital of $75,000, to operate mica properties and manufacture mica products. The incorporators are W. B. Merrill and L. L. Tapley, Heflin.

THE TRINITY OIL CORP., Jersey City, N. J., has been incorporated under Delaware laws with capital of $3,000,000, to manufacture petroleum products. The company is represented by the Registrar & Transfer Co., 900 Market St., Wilmington, Del.

THE HAMPTON ROADS EXTRACT CO., Norfolk, Va., has been incorporated with a capital of $25,000, to manufacture chemical extracts, compounds, etc. Nicholas Pavlou is president, and W. W. Ritter, secretary, both of Norfolk.

THE CARNAHAN OIL & REFINING CO., Augusta, Me., has been incorporated under state laws to manufacture refined oil products. D. A. Leland is president; and W. T. Gardiner, treasurer. The company is represented by C. L. Andrews, Augusta.

THE EASTERN CHEMICAL CO., Wilmington, Del., has been incorporated under state laws with a capital of $250,000, to manufacture chemicals and chemical byproducts. The company is represented by the Corporation Trust Co. of America, du Pont Bldg., Wilmington.

THE H. B. VITT CO., Richmond, Staten Island, N. Y., has been incorporated with a capital of $10,000, to manufacture paints, oils, etc. The incorporators are H. and C. Vitt, and W. Stumpf. The company is represented by F. W. Clifford, Stapleton, S. I.

THE ARKANSAS PLATINUM DEVELOPMENT CO., Little Rock, Ark., has been incorporated with a capital of $350,000, to operate platinum properties and manufacture platinum. The incorporators are J. E. McLean, T. W. Mattingly and C. C. Williams, Little Rock.

THE FORDS PORCELAIN WORKS, INC., Perth Amboy, N. J., has been incorporated with a capital of $1,000,000, to manufacture sanitary ware. The company will succeed the organization of the same name, now operating two plants at Perth Amboy, and one at Fords. Abel Hansen is president.

THE SURE CHEMICAL CO., Pittsburgh, Pa., has been incorporated with a capital of $100,000, to manufacture chemicals, chemical byproducts, etc. The company is represented by the Capital Trust Co. of Delaware, Dover, Del.

New Publications

THE ANNUAL REPORT of the Director of the Bureau of Foreign and Domestic Commerce to the Secretary of Commerce for the fiscal year ended June 30, 1921, has been issued.

THE UNIVERSITY OF IDAHO has issued Bull. 13, on "The Availability of Western Wood Oils for Flotation Concentration." Part I, on the Production of the Oils, is by I. W. Cook, and Part II, on the Flotation Properties of the Oils, is by Louis A. Grant.

THE BUREAU OF MINES AND GEOLOGY of the State of Idaho has published four pamphlets. No. 1 is on Interfacial Tension Measurements and Some Applications to Flotation, by Robert B. Elder; No. 2 is on Size of Mineral Particle in Relation to Flotation Concentration, by A. W. Fahrenwald; No. 3 is on Testing Ores for Flotation, by A. W. Fahrenwald, and No. 4 on Differential Flotation, by A. W. Fahrenwald.

INDUSTRIAL OPPORTUNITIES IN NEW JERSEY is the title of a new publication issued by the Land Registry, Department of Conservation and Development, State House, Trenton, N. J.

THE CITIZENS' NATIONAL BANK of Decatur, Ill., has prepared a series of illustrated folders entitled "Our National Resources." A brief description of the occurrence, mining and uses of the more important metals, salt and non-metallic elements is given in a popular manner. The illustrations are interesting and instructive. The series presents an interesting example of the application of technical information to business advertising.

THE ROYAL SOCIETY OF ARTS, London, England, has issued a pamphlet on Major G. W. C. Keye's address delivered before the Royal Society of Arts on "X-Rays and Their Industrial Applications."

Coming Meetings and Events

AMERICAN CHEMICAL SOCIETY will hold its spring meeting at Birmingham, Ala., April 4 to 7, 1922.

AMERICAN ELECTROCHEMICAL SOCIETY will hold its spring meeting in Baltimore, April 27, 28 and 29, 1922. Headquarters will be at the Emerson Hotel.

AMERICAN FOUNDRYMEN'S ASSOCIATION will hold its next convention and exhibit at Rochester, N. Y., during the week of June 5, 1922. Meetings will be held in the spring instead of in the fall as heretofore.

AMERICAN SOCIETY FOR STEEL TREATING will hold a sectional meeting, Friday, March 3, at the Hotel McAlpin, New York City. A sectional meeting will also be held at the Bureau of Mines auditorium, Pittsburgh, Pa., on May 25 and 26. The International Steel Exposition and Convention of the society will be held in the General Motors Bldg., Detroit, Mich., Oct. 2 to 7.

AMERICAN SOCIETY FOR TESTING MATERIALS will hold its twenty-fifth annual meeting June 26 to July 1, at Atlantic City, N. J. Headquarters will be at the Chalfonte-Haddon Hall Hotel.

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY will hold a meeting at Lyons, France, June 27 to 30.

IRON AND STEEL INSTITUTE (British) will hold its annual meeting on May 4 and 5 at the House of the Institution of Civil Engineers, Great George St., S. W., 1, London.

NEW JERSEY CHEMICAL SOCIETY holds a meeting at Stetters Restaurant, 842 Broad St., Newark, N. J., the second Monday of every month.

STAMFORD CHEMICAL SOCIETY, Stamford, Conn., holds a meeting in the lecture room of the local high school on the fourth Monday of each month, except June, July, August and September.

The following meetings are scheduled to be held in Rumford Hall, the Chemists' Club, New York: March 10—American Chemical Society, Nichols Medal; March 24—Society of Chemical Industry, regular meeting; April 21—Society of Chemical Industry (in charge), American Electrochemical Society, Société de Chimie Industrielle, American Chemical Society, joint meeting; May 5—American Chemical Society, regular meeting; May 12—Société de Chimie Industrielle (in charge), American Chemical Society, Society of Chemical Industry, American Electrochemical Society, joint meeting; May 19—Society of Chemical Industry, regular meeting; June 9—American Chemical Society, regular meeting.